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THE TEMPERATURE TRANSMITTED BY INCLINED INCANDESCENT RADIATORS.

BY CAPTAIN JOHN ERICSSON.

From "Engineering."

The notion has long prevailed that the surface of an incandescent body projects rays of equal energy in all directions. Laplace, having full confidence in the correctness of this assumption, founded upon it the well-known demonstration, proving that the radiant energy which emanates from the receding surface of the sun, possesses greater intensity than that emanating from the central regions of the luminary. But, actual observation having shown that the radiant energy from the sun's border, so far from being more intense, is considerably less than from the centre, the persistent mathematician was driven to the alternative of proving that the retardation produced by the sun's atmosphere neutralizes the assumed increase of intensity of the radiation emanating from the receding solar surface. How completely the ready symbols, manipulated by the great master, establish the truth of his proposition, will be found on reference to "Méchanique Céleste," tome iv., pp. 284-288; the result of the demonstration being that the solar atmosphere absorbs $\frac{1}{11}$ of the entire energy emanating from the radiant surface! Evidently Laplace did not regard solar radiation as molecular energy capable of being converted into dynamic energy, or he would have perceived the impossibility of $\frac{1}{11}$ being absorbed by the solar atmosphere. It is not intended to enter on a criticism of the famous demonstration, but the question is so intimately connected with the subject under consideration that a brief reference to the main points will be necessary to show on what grounds the conclusion was based that, but for the retardation produced by the solar atmosphere, the radiant energy of the luminary would be increased in the ratio stated. Accepting Laplace's assumption that the intensity of the radiation increases with the obliquity of the rays (owing, it is supposed, to the increased number of rays contained in a given section), we must admit that the radiant energy from the regions near the sun's border will be greatly enhanced. And since it has been found by actual observation that no increase of intensity takes place, the inference cannot be resisted that the retardation produced by the solar atmosphere neutralizes the increased intensity occasioned by obliquity. It is evident that this retardation may be determined by calculating the assumed increase of intensity corresponding with the obliquity of the rays; but this calculation, it is also evident, will not show the full extent of retardation, since not only is there no increase, but a considerable *diminution* of intensity towards the sun's border. Hence, the amount of retardation determined

agreeable to the theory that the radiant intensity is increased by the obliquity of the rays, will be still further augmented. The reader will readily perceive from this brief explanation, on what grounds Laplace's amazing enunciation is chiefly based, that "if the sun were stripped of its atmosphere it would appear 12 times as luminous."

The foregoing reference to theories promulgated nearly a century ago, when solar radiation was but imperfectly understood, will be deemed irrelevant by those who have not made themselves acquainted with the contents of the recent work on the sun, by Père Secchi ("Le Soleil," P. A. Secchi, Paris, 1870). This eminent physicist, who has devoted more time to the investigation of the subject than any one else, now presents calculations proving that the retardation offered by the solar atmosphere to the passage of the rays, is so great that only a fraction of the radiant heat enters space. He sums up his investigation by the following positive statement: "1st. At the centre of the disc, perpendicularly to the surface of the photosphere, the absorption arrests about $\frac{2}{3}$, more exactly $\frac{63}{100}$, of the total energy. 2d. The total action of the absorbing envelope of the visible hemisphere of the sun is so great, that it allows only $\frac{12}{100}$ of the entire radiation to pass, the remainder, that is to say $\frac{88}{100}$, being absorbed." Persons accustomed to compare mechanical equivalents, especially those who possess practical knowledge of the amount of mechanical power developed by the radiant heat emitted by incandescent bodies, cannot consistently accept Père Secchi's theory. Nor will the assumption that the radiant heat is absorbed by molecular motion in the solar atmosphere be accepted by those who take the practical view of the matter, that the dynamic energy developed by the heat rays projected from the photosphere must enter space, less only the amount of work performed during the passage through the solar atmosphere. Investigations conducted by means of the solar calorimeter (described in "Engineering," July 15, 1870), show that when the earth is in aphelion, the dynamic energy of the sun's radiant heat on entering the earth's atmosphere is 6.35 thermal units per min. upon 1 sq. ft. of surface. The dispersion of the rays when the earth is in the position referred to, being in the ratio of 1: 47,567, it will be seen that each sq. ft. of the photosphere emits at least $47{,}567 \times 6.35 = 302{,}050$ units of heat per min. Secchi says that only $\frac{1}{8}$ of the heat emitted passes through the sun's atmosphere. Accordingly $7 \times 302{,}050 = 2{,}114{,}350$ units per minute are absorbed. Now the development of one horse power requires $\frac{33000}{773} = 42.7$ units of heat per minute; hence the energy supposed to be absorbed represents a *continuous* dynamic force, amounting to $\frac{2114350}{42.7} = 49{,}516$ horse power for each sq. ft. of the surface of the photosphere. Considering that the sun's atmosphere is composed of highly attenuated gases, containing a very small quantity of matter, probably not much more on a given area than the terrestial atmosphere, the assumption that the stated enormous energy is continually being arrested by the solar atmosphere, is utterly at variance with the principles of mechanics. But as it is not our intention on this occasion to combat the erroneous, not to say absurd, doctrines relating to solar heat, contained in the pages of "Le Soleil," let us at once proceed to investigate the subject of radiant heat emanating from incandescent bodies. If we can prove the fallacy of the assumption that radiators emit heat rays of equal energy in all directions, we destroy the principal foundation supporting the false theory which has led to the conclusion that only $\frac{1}{8}$ of the energy developed by the sun penetrates its atmosphere. The subject will be presented in two sections: 1st. Radiant heat emanating from inclined incandescent planes. 2d. The radiation of incandescent spheres, the first section only to be discussed in the present article.

The reader is aware that the experiments relating to the radiant heat of solid bodies, an account of which has previously appeared in "Engineering," were so managed that the atmospheric air was excluded from the radiator and from the thermometer employed. The radiation of flames, it has been shown in previous articles, cannot be ascertained within a vacuum, nor is it easy to confine solid *incandescent* radiators of large size within an exhausted vessel, while ascertaining their radiant power. Some expedient, therefore, must be adopted to prevent the disturbing influence of the surrounding air on the recording thermometer, when

experimenting within a vacuum is not practicable. Evidently this can only be effected by keeping the air surrounding the bulb in a perfectly quiescent state. The following description will show the device which has been resorted to.

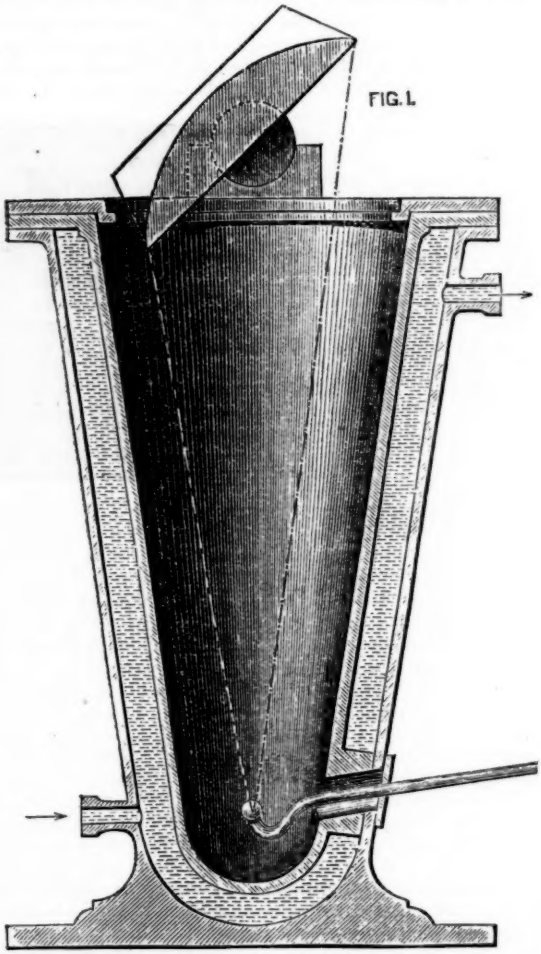
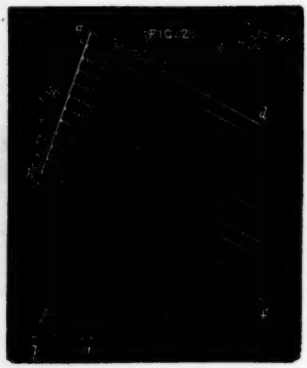


Fig. 1 represents a vertical section of a conical vessel, the bottom of which is semispherical, the top being open and provided with a wide flange. A broad ring, with journal bearings attached on opposite sides, is bolted to the flange mentioned; a circular disc of cast iron, the back of which is semispherical, being suspended across the top of the conical vessel, supported by journals resting in the bearings adverted to. A jacket, through which a stream of cold water is passed during experiments, surrounds the conical vessel, the recording thermometer being inserted near its semispherical bottom. The tube of the thermometer is bent, in order that the entire upper half of the bulb may be exposed to the radiant heat of the circular disc, while the lower half is inclosed in a casing composed of non-conducting materials. It scarcely needs explanation that the air within the

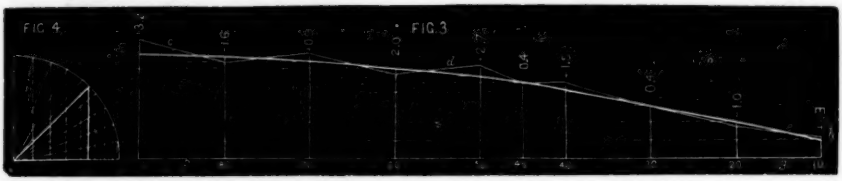
semispherical chamber containing the thermometer will remain in a quiescent state, since the heat is applied from above. The cold air at the bottom obviously cannot be replaced by heated air from the top. At the same time, the trifling amount of heat carried downward by conduction, from particle to particle of the confined air, will be completely absorbed by the surrounding cold vessel. Consequently, the action of the enclosed thermometer will be sufficiently undisturbed to afford reliable indications. The inclination of the radiating circular disc is regulated by a graduated quadrant and an index secured to one of the journals, in such a manner that it may be readily detached and again applied. A casing, likewise readily secured and detached, is applied to the disc in order to prevent radiation from the semispherical back towards the thermometer, when the inclination is great. During experiments, the apparatus is placed near an air furnace, hose being attached for supplying a constant stream of water through the jacket. The furnace having been charged with combustibles capable of producing a steady fire, and heated to the requisite degree, the disc is inserted. Having remained in the furnace until the color of the metal approaches bright orange, the disc is quickly withdrawn and placed over the open conical vessel, supported by the journals, as shown by our illustration.

Agreeable to the theory, the correctness of which we are going to disprove, the incandescent disc, placed at the inclination shown in Fig. 1., will transmit a higher temperature to the thermometer than if it were placed at a greater angle to the vertical line ; the reasons assigned for this assumption being that the same number of radiating points are presented by the disc, and the same number of rays of equal energy emitted in either position, while in the former they are more concentrated than in the latter. This explanation involves the proposition that parallel rays projected at an acute angle, from a given number of radiating points, transmit *greater* intensity than an equal number of parallel rays projected at a less acute angle to the radiant surface. That this proposition, although untenable, is very plausible, will be seen by reference to Fig. 2. Let *a b* represent the inclined adiant surface, and *a c b* the several radiating points projecting heat rays towards the spaces *d f* and *k g*. The number of radiating points and the number of heat rays projected being alike in each case, while the space represented by *k g* is only $\frac{1}{3}$d of that represented by *d f*, it must be admitted, if we assume all rays to possess equal energy, that the concentration of



heat within *k g* is three times greater than within *d f*. In other words, that a given area within *k g* receives three times more heat than an equal area within *d f*. This apparently correct view of the question, and its application to spheres, led Laplace astray in his demonstration concerning solar intensity. In the second part of our discourse, which, as already stated, will be devoted to incandescent spheres, the influence of the spherical form on radiant intensity will be fully considered. In the meantime, we must admit that the demonstration contained in Fig. 2 is unanswerable under the stipulated condition that all heat rays emitted by a radiator possess equal energy. Our task, therefore, will be to show, practically, that the stated condition, is based upon untenable ground. Having already made ourselves acquainted with the apparatus constructed for this purpose, we may at once proceed to consider the results of the experiments which have been instituted. It will be evident that owing to the high temperature of the disc, it will cool very rapidly after being removed from the furnace and placed in position over the conical vessel, and that the thermometer, however sensitive, will require so long a time before reaching maximum indication, that only one inclination can be ex-

perimented on at a time, thus rendering reheating indispensable for each change of inclination. The number of changes of inclination during the investigation have, therefore, been limited to ten, beginning with 90 deg., and ending with 10 deg. inclination to the vertical line. It will also be evident that the high temperature renders it practically impossible to impart exactly the same degree of incandescence at each operation. The best that can be done is to maintain the furnace at a uniform temperature, and to expose the disc to the action of the heat during an equal time for each operation. This method, though not precise, has, it will be shown, conclusively established the fact that the temperature transmitted to the stationary thermometer by the radiant heat, varies in the exact ratio of the sines of the angles formed by the face of the disc, and a line drawn from its centre through the centre of the bulb. The result of an experiment made with great care will be found recorded by the diagram, Fig. 3, in which the ordinates of the curve, *a b*, represent the



sines of the angles formed by the disc and the line mentioned, the ordinates of the irregular line, *c d e*, representing the temperature transmitted to the stationary thermometer. The figures inserted below the base line, *f g*, show the number of degrees of inclination corresponding with the sine represented by each ordinate, while the figures above the curve, *a b*, show the discrepancy between the calculated and the actual temperature transmitted to the stationary therm ometer. It will be found on inspection that the mean difference of the actual and the calculated temperature *above* the curve is 1.94 deg., that *below* the same being 1.08 deg.; hence the mean discrepancy is only 0.86 deg. Fahr. Considering the difficulty of imparting an equal temperature at each operation during the experiments, this discrepancy between the calculated and the actual temperature transmitted by the radiation of the incandescent disc is unimportant. We are compelled, therefore, to accept the conclusion that the temperatures vary exactly as the sines of the angles of inclination of the radiant surface. It has been deemed proper, in view of the great importance of this conclusion, and in order to render the subject clearly understood, to introduce Fig. 4, showing the several angular positions of the incandescent disc during the investigation. Dotted lines, it will be seen, have also been introduced, connecting these angular positions with the corresponding ordinates of the curve *a b*, in Fig. 3. A mere glance at the geometrical representation contained in Figs. 3 and 4, will show that the temperatures indicated by the curve correspond exactly with the sines of the angles of inclination of the disc. Bearing in mind the facts thus established, let us again refer to Fig. 2, in which the space *k g* is $\frac{1}{3}$ of the space *d f*. We are now enabled to demonstrate that the temperature within the former will be only $\frac{1}{3}$ of the temperature within the latter. Laplace and his followers, assuming the reverse to be the case, viz.: that the temperature within *k g* will be 3 times higher than within *d f*, their estimate of the radiant intensity of inclined surfaces will obviously be too high in the inverse ratio of the sines of angles of inclination. The consequence of this grave mistake, with reference to the radiant power of incandescent spherical bodies, will be discussed in the next article on radiant heat.

NEW YORK, December 15, 1871.

DR. ROBERT HUNTER, of Cleveland, Ohio, is reported to have invented a method of propelling canal boats that promises to be highly successful. An india-rubber plate is attached to the stern of the boat and is actuated by steam in the manner of a fish's tail.

BLAST FURNACE ECONOMY.*

By THOMAS M. DROWN.

From the "Bulletin of Am. Iron and Steel Association."

We have learned that it is coal that does the work in the blast furnace, and that the work is twofold; first, reducing; second, heating. The whole question of economy in blast furnace management turns around this point of the amount of coal used.

The history of the iron manufacture exemplifies well the importance of this matter. In the year 1829, there were used in Scotland 8 tons of coal in the form of coke to make 1 ton of pig iron; the amount at the present day has been reduced to nearly 1 ton of coal to the ton of pig iron.

Let us study the subject systematically, so as to learn all the possibilities in the case.

We have already seen that a short distance above the tuyeres only carbonic oxide exists, and no carbonic acid, and that the heat of the blast furnace, considered as a whole, is only that which would be produced by burning all the fuel to carbonic oxide—an amount which is comparatively small. Again, ½ of the fuel is consumed before the tuyeres to carbonic acid, and produces the intense heat necessary for carburizing the iron and melting the iron and slag. Now, it is upon this half of the fuel that the working of the furnace depends. Suppose, for example, that a furnace is working satisfactorily, producing a highly carburized iron and a well melted normal cinder. If the amount of fuel charged be lessened, what will be the effect? There will naturally be less heat before the tuyeres, the iron will combine with less carbon, and will be consequently whiter and more infusible, and the slag will be imperfectly melted.

The question arises, therefore, how can we maintain the same temperature before the tuyeres with a smaller amount of fuel? The means employed are, first, to heat the descending charge; second, to heat the ascending blast.

The charge must necessarily become heated in descending as it meets the hot ascending gases, but in low furnaces the heat of the gases is not completely abstracted and much goes to waste at the top of the furnace. To utilize this heat, the furnace must be made higher so as not to allow the gases to escape until they have transferred nearly all their sensible heat to the charge. The profitable limit of height is therefore attained when the gases given off are comparatively cool.

There is another limit, however, and that is the hardness of the materials of the charge and their ability to resist crushing and packing. The highest furnaces yet constructed are a pair in the Cleveland district, in England. These are 150 ft. high. They smelt the hard Cleveland ironstone with Durham coke, which is noted for its hardness. Crumbling ores like some of the brown hematites, and soft fuel, would be entirely inadmissible under such conditions.

The economy attained in high furnaces, supposing all conditions to be favorable to their use, is very considerable, and the cause of the economy lies mainly in the utilization of the sensible heat of the gases of the furnace.

Besides this direct method of heating the charge, there is also an indirect method, which consists in calcining the ore and limestone, or both, before charging. One of the effects of the heat of the furnace on the charge, as we have learned already, is the driving off of volatile ingredients, as water from the ore and carbonic acid from the limestone; if, therefore, this be effected outside of the furnace, the heat which was before consumed in performing this work will be available for heating. The saving of fuel consequent on using calcined ore and limestone is considerable, but local circumstances must always decide whether it be economically advantageous. Where cheap coal cannot be obtained, or where the additional expense of handling would be great, it may be cheaper to effect the calcination in the upper part of the furnace. The most favorable conditions are present when the calcination can be effected in kilns heated by waste blast furnace gases.

We might mention a third means of

* Extract from a Lecture delivered before the Franklin Institute, Jan. 23, 1872.

economizing fuel in this division, namely, by producing less cinder. The amount of cinder formed in any instance is of course dependent on the amount of earthy impurities in the ore. The more silica we have in an ore, the more lime is required to flux it, and the more fuel is required to melt the resulting cinder. The generality of iron ores are silicious, but there occur not unfrequently argillaceous and calcareous ores, which, when mixed with silicious ores, may give a self-fluxing charge. A cinder is of course formed, but owing to the charge being enriched by the judicious mixing of ores it is smaller in amount, and consequently less fuel is required to melt it.

The saving effected by the additional heating of the charge is, however, insignificant in comparison with that attained by heating the blast. This discovery was made by James Beaumont Neilson, of Glasgow, in 1828. The first apparatus for heating the blast was put up at the Clyde Iron Works, in 1830, and in 1835 hot blast was in use in all the iron works in Scotland. The following account of these early experiments will show the remarkable saving effected. In the first 6 months of 1829, when cold blast was employed, there were used 8 tons 1¼ cwt. of coal, in form of coke, to produce 1 ton of iron. When using 8 cwt. of coal to heat the blast to 300 deg. F., there were used 5 tons 3¼ cwt. coal per ton of pig iron, a saving of 2 tons 18 cwt. To put the same in other words: 8 cwt. of coal burned outside of the furnace and the heat forced into the furnace in the form of hot air was equal to 2 tons 18 cwt. used in the furnace itself. This result was so extraordinary that it baffled explanation, and it is only very recently that this phenomenon has been satisfactorily explained. J. Lowthian Bell, an English iron master, whose researches into the theory of the blast furnace process have been the most painstaking and reliable that we possess, shows conclusively that the cause lies in the fact that the coal consumed in heating the blast outside of the furnace is converted into carbonic acid, that is, we obtain the total amount of heat possible from its combustion, while in the furnace itself the coal is only burnt to carbonic oxide and gives less than ⅓ of the heat it is capable of producing. The figures representing the consumption of coal per ton of pig iron at the present day differ widely from those given above for the years 1829–30. Still the saving in using hot blast is no less marked now than then. The temperature of blast now generally employed is from 750 to 1,000 deg. F., and the saving is about 10–11 cwt. of coke per ton of pig iron.

As has been before incidentally mentioned the waste gases of the blast furnace are collected and burned to heat the blast, consequently no extra expenditure of coal is necessary. Ordinarily the amount of gas obtained is more than sufficient for this purpose, a surplus being available for heating boilers for raising steam. It has been mentioned that it is a very general practice to draw off the gas in part by channels in the upper part of the walls of the furnace, while another part escapes from the middle of the furnace mouth and is wasted. Again, many furnaces are constructed with tops which remain completely closed except in the intervals of charging. A complete utilization of the coal is thus obtained, and no furnace can be said to work with a proper regard to economy, which allows a valuable gaseous fuel to escape into the air. It is replied by the advocates of open-mouth furnaces that the escaping gas is over and above what is needed for heating the blast and boiler. It should then be made to do other work or should not be produced at all. In England, where the old adage of "pence making pounds" is better understood than it is with us, the propriety of saving the small amount of gas which escapes at the moment of charging has been discussed—rather a refinement of economy, but eminently suggestive.

These, then, are the points to be borne in mind with reference to a saving of fuel: First, the production of as small amount of combustible gas as possible; second, the complete and profitable utilization of what is produced. A furnace producing but a small amount of carbonic oxide or of combustible gas, indicates, other things being equal, economical working, and, on the other hand, an excess of carbonic oxide indicates waste. A theoretically perfect blast furnace would be one in which all the coal passed out as carbonic acid, but such a condition of affairs will probably never be attained in practice.

There is still another very interesting

point in this connection having both a scientific and an economic side, which has received but little attention. I have said that ½ of the fuel may be regarded as heating or melting fuel while the whole is available for reduction. Suppose now that the ore should reach the vicinity of the tuyeres only partially reduced, that is, still containing some oxygen, what would be the consequence? This residual oxygen will be taken up by the coal in front of the tuyeres; in other words, the coal which should be used exclusively for heating and melting has to do the work of reduction. One and the same amount of fuel cannot do both, and if, therefore, the duty of reduction be superadded to that of heating, more coal must necessarily be employed.

It is not easy to ascertain in any particular instance whether imperfectly reduced ore reaches this low point in the furnace, as we have no means of inspecting the contents of the furnace near the tuyeres, still many facts point toward the possibility of its occurrence under certain circumstances. Let us study what are the conditions which tend to counteract such a state of affairs. They may be enumerated as follows: 1st. The greater porosity of the ore; 2d. The smaller the fragments of ore; and 3d. The greater length of time the ore is exposed to the action of the reducing gases.

1st. The greater porosity of the ore. We can readily understand that a large hard compact mass of ore would be much more slowly reduced than a porous mass, into the interstices of which the gas could find ready access. Some ores are naturally porous, as some of the brown hematites; others, like the magnetites, are extremely compact. The means employed to increase the porosity of ores is roasting. This acts on hydrous or carbonated ores mainly by driving off water and carbonic acid, leaving them more or less cellular. The action of roasting on hematites and magnetites is simply to produce cracks and crevices into which the gas can penetrate.

2d. The size of the ore masses. It is reasonable to suppose that the larger the masses of ore the longer time will be required for complete reduction. No size can be given as best adapted to all ores or all furnaces, but it is a matter of great importance that all the pieces should be as nearly as possible of one size in the same furnace. There is a limit to the degree of comminution of ores or other materials of the charge. If they are too small, approximating to sand, for instance, the superincumbent pressure will cause them to pack so that the gases cannot get through at all, or the gases may form channels and ascend unequally, reducing some portions more completely than others. Many of the brown hematites come in this fine condition and frequently produce irregular working of the furnace. It would be well in such cases if such fine ores could be made into coherent lumps, though it is doubtful if this could be effected profitably.

3d. The length of time the ores are exposed to the action of the reducing gases, is a very important element in this blast furnace economy. It takes both time and heat to effect the reduction of ore by carbonic oxide. The temperature at which reduction begins is variously stated by different investigators, probably on account of the difference of ores experimented upon. Bell gives 424 deg. Fahr. as the temperature at which the reduction of the Cleveland ironstone begins. Scheerer gives 750 deg. Fahr., Tunner as high as 1,250 deg. Fahr. as the point of incipient reduction. There can be but little doubt that the numbers last given are too high. Bell states that reduction proceeds most rapidly at 723 deg. Fahr. Whatever the most favorable temperature may be, a certain time is necessary for complete reduction. As to the length of time, we can only state that the harder the ores and larger the fragments, the more time will be required. The rate of descent of the charge depends on the rate at which the furnace is driven, that is, on the amount of fuel consumed in a given time, and hence on the amount and pressure of blast. The greater the production of a furnace in a given time, other things being equal, the more economically it works. We cannot, therefore, think of increasing the contact of the ore with the gas at the expense of decreased production. Increasing the height of the furnace can only be effective in this regard as long as the gas at the mouth has a temperature equal or above that which is requisite for the reduction of the ore. There is but one other conceivable mode of making the reducing gas act more thoroughly on

the ore, and that is to decrease the velocity of its ascent by widening the furnace, and make the walls expand outwards and upwards. This is the case with all furnaces at the lower part where they expand into the boshes, but in almost all instances the walls incline inward again towards the top. The Rachette furnace is constructed on the principle mentioned, namely, with walls expanding from bottom to top. This furnace has not proved very successful in iron smelting, but its failure —if failure it can be called—cannot fairly be attributed to its expanding walls, but rather to its rectangular section. Lead furnaces built on the Rachette principle proved to be in many respects superior to the furnace form previously in use; but when the rectangular section was abandoned, and a combination made of circular section with expanding walls, the improvement in working and yield was very great, and it seems not at all improbable that the same construction would work equally well in the case of iron. That the descent of the charge would be much more uniform in a furnace of this construction, I think there can be no doubt.

Truran, formerly engineer of the Dowlais Works, was the first to advocate wide mouth furnaces to diminish the velocity of the ascending gases. More recently, Troska, in an able discussion of this subject, has arrived at the same conclusion as Truran, and recommends furnaces with vertical walls from the boshes upward. The same argument which supports his conclusions may, however, be fairly extended to furnaces with gradually expanding walls. Of course, the best angle of construction is a matter which must be determined by experiment, and will differ with different ores. It is interesting to note, in this connection, the fact, long known, that in charcoal furnaces the consumption of fuel per ton of pig iron produced decreased as the angle of the boshes was lessened, which doubtless resulted from the diminished rapidity of the gases in this part of the furnace.

To briefly recapitulate, economy in blast furnace management may be attained in the following directions :

1. Heating the charge.
   - *a.* Direct, by increasing the height of the furnace.
   - *b.* Indirect, by calcining ore and limestone.
2. Enriching the charge.
3. Heating the blast.
4. Complete and profitable utilization of the waste gases.
5. Rendering the ores porous by roasting.
6. Breaking ores to uniform and suitable size.
7. Retarding the ascent of the reducing gases.

PROBLEM OF THE RAFTERS.

By DE VOLSON WOOD.

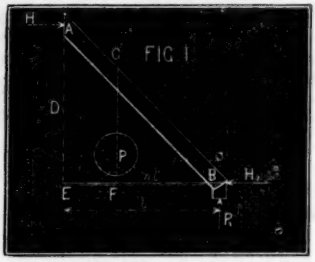
From "Journal of Franklin Institute."

The sloping timbers at the ends of a roof truss are called rafters, whether the truss is a "king post," a "queen post," or other form. When the load is applied at the joints of the truss, the solution seems to present little or no difficulty :—at least authors do not differ in their results. But when the load is uniformly distributed over the rafter, or is applied at points along the rafter, authors differ in their results, as may be seen by examining Trautwine's "Engineer's Pocket Book," pp. 247–252. Mr. Trautwine gives his own solution, and refers to Rankine's "Civil Engineering," p. 470, for the solution which is commonly given. I find, according to the solution given below, that the horizontal pressure at the upper end is the same as that given by Prof. Rankine, but the longitudinal compression along the rafter is not correctly given by any author, so far as I am acquainted with them.

In order to simplify the problem as much as possible, we will at first consider a single rafter supporting a single weight, P, which is applied at any point. The lower end of the rafter, B, is held in the usual way by resting upon a support which sustains the vertical pressure, and by a tie rod which resists the horizontal push. The upper end is held by a horizontal force, which in any case is sufficient to hold the system in equilibrium.

In Fig. 1 let

A B = the length of the rafter.
D = A E = the rise.
l = E B = the run of the rafter, or its horizontal projection.
$n\,l$ = B F = the horizontal distance of the point of application of the weight from B.
θ = the angle B C F = B A E.
P = the weight which is applied at C.
P_1 = the reaction of the support B.
H = the horizontal pressure at A.
H_1 = the horizontal pressure at B.



It is a principle of statics that the algebraic sum of the vertical components of all the forces in a system in equilibrium is zero,—and the same is true of all the horizontal components. Or, in this case, the sum of all the forces acting downward, equals the sum of all those acting upward; and the sum of the horizontal forces pressing to the right equal those pressing towards the left. Hence

$$P = P_1, \text{ and}$$
$$H = H_1.$$

Taking the moments about B, we have

$$H\,D = P\,n\,l$$
$$\therefore\ H = n\,P\,\frac{l}{D} = n\,P\,\text{tang}\,\theta. \qquad (1.)$$

Taking the moments about A, we have

$P_1\,l = H_1\,D + (1-n)\,P\,l$, or making $P = P_1$, we have

$$P\,l = H_1\,D + (1-n)\,P\,l.$$
$$\therefore\ H_1 = n\,P\,\frac{l}{D} = n\,P\,\text{tang}\,\theta \text{ as before;}$$

Or, assuming that $H_1 = H$ and we have

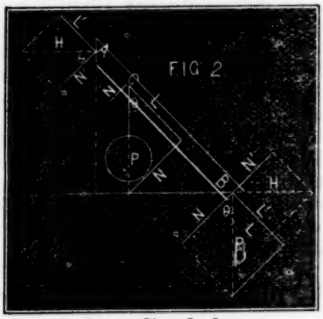
$$P_1\,l = H\,D + (1-n)\,P\,l,$$

in which substitute the value of H from (1) and we have

$$P_1\,l = n\,P\,l + (1-)\,n\,P\,l$$
$$\therefore\ P_1 = P \text{ as before.}$$

Next find the compression along the rafter.

Instead of the single horizontal force at A, we may substitute two other forces such that the resultant of the two shall equal H. The two forces will evidently produce the same result as H. As we seek the longitudinal effect, let one of the components be taken in that direction and call it L^1. The other component, to produce no longitudinal effect, must be perpendicular to the rafter. Call it N^1. These forces are shown in Fig. 2.



Hence we immediately have

$$L^1 = H\sin\theta = n\,P\,\text{tang}\,\theta\sin\theta = n\,P\,\frac{\sin^2\theta}{\cos\theta} \qquad (2.)$$

$$N^1 = H\cos\theta = n\,P\,\text{tang}\,\theta\cos\theta = n\,P\sin\theta \qquad (3.)$$

The latter component N^1 produces only bending, and is resisted by a component of the applied weight, P. The former component produces compression only, and is the only compressive force between A and C. At C this force is increased by a component of the weight.

Let N = the normal component of P, and
L = the longitudinal component of P.

Then $N = P\sin\theta$, and . . , (4.)
$L = P\cos\theta$ . . . (5.)

Between C and B the total longitudinal compression is

$$L^1 + L = n\,P\,\frac{\sin^2\theta}{\cos\theta} + P\cos\theta =$$
$$\frac{P}{\cos\theta}\left[n\sin^2\theta + \cos^2\theta\right] \quad . \quad . \quad . \qquad (6.)$$

As a check upon the work we may find the reactions of the forces at B.

For H we have the two components

$$L^1 = H\sin\theta.$$
$$N^1 = H\cos\theta.$$

And for P we have

$$L = P\cos\theta.$$
$$N = P\sin\theta.$$

Hence, the resultant longitudinal pressure is

$$L + L^1 = P\cos\theta + H\sin\theta =$$
$$\frac{P}{\cos\theta}\left[n\sin^2\theta + \cos^2\theta\right] \text{ as before.}$$

The resultant normal pressure is

$$N - N^1 = P\sin\theta - H\cos\theta = P\sin\theta - n\,P\sin\theta =$$
$$(1-n)\,P\sin\theta \quad . \quad . \quad (7.)$$

Adding (3) and (6) we have

$$P \sin \theta,$$

which is the same as (4), as it should be, since the normal pressures at the ends should be equal and opposite to the normal component of the applied weight.

DISCUSSION.

1. If the rafter is vertical, $\theta = 0$, and the compression on the upper part, between A and C, is, from (2),

$$L^1 = 0,$$

and the compression on the lower part, between C and B, from (6), is

$$L = P$$

and the horizontal thrust is, from (1), equal to zero.

2. If the rafter has any inclination and P is placed at A, n is equal to 1 in all the equations, and (1) gives

$$H = P \operatorname{tang} \theta,$$

which is the value given for this case by all writers. Equation (2) gives

$$L^1 = \operatorname{tang} \theta \sin \theta,$$

but, as in this case, C falls upon A, and hence A C $= 0$, this merely gives the component of H in that direction, and does not give the compression upon any finite length of the rafter. Equation (6) gives

$$L + L^1 = \frac{P}{\cos \theta} = P \sec \theta,$$

which is also the value given by all writers for the compression upon a brace where the total load is placed at the upper end of the brace.

3. If P is placed at the lower end of the beam, $n = 0$, and equations (1), (2) and (6) give

$$H = 0$$
$$L^1 = 0,$$
$$L + L^1 = P \cos \theta;$$

the last of which is the longitudinal component of P; but as in this case C falls on B, the resultant compression does not apply to any finite portion of the rafter.

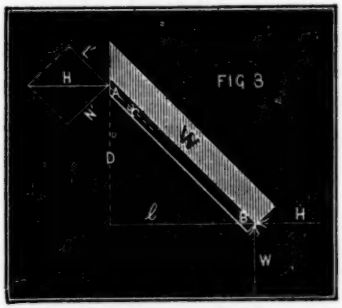
4. Let the rafter be horizontal, then $\theta = 90°$, and equations (1), (2) and (6) become

$$H = \infty$$
$$L^1 = \infty$$
$$L + L^1 = 0 + \infty.$$

5. If P be applied at the middle, $n = \frac{1}{2}$, and we have

$$H = \tfrac{1}{2} P \operatorname{tang} \theta$$
$$L^1 = \tfrac{1}{2} P \operatorname{tang} \theta \sin \theta$$
$$L + L^1 = \frac{P}{\cos \theta}\left[\tfrac{1}{2} \sin^2 \theta + \cos^2 \theta\right]$$

By supposing that P is applied at different points, and taking the sum of the results, we may find the effect of several weights applied simultaneously.



Now suppose that the rafter is uniformly loaded over its whole length, and let n = the load on a foot of length of the rafter, and W = the total load.

(Those who compare this solution with Rankine's—"Civil Engineering," p. 470—will observe that he calls W the load on two rafters, and hence $\frac{1}{2}$ W is the load on one rafter.) Taking the moments about B and observing that the lever arm of W is $\frac{1}{2} l$, and we have

$$H D = W \tfrac{1}{2} l. \therefore H = \tfrac{1}{2} W \frac{l}{D} = \tfrac{1}{2} W \operatorname{tang} \theta. \quad (8.)$$

If x be any distance from A measured along the rafter, $w x$ will be the load on that length, and the longitudinal component of it will be, according to equation (5),

$$L = W x \cos \theta,$$

and the longitudinal component of H is

$$L^1 = H \sin \theta.$$

Hence the total compression at any section whose distance is x from A, is

$$L + L^1 = w x \cos \theta + H \sin \theta = w x \cos \theta + \tfrac{1}{2} W \operatorname{tang} \theta \sin \theta. \quad . \quad . \quad . \quad (10)$$

DISCUSSION.

1. At the lower end $x =$ A B, and $w x$ becomes w A B $=$ W, and hence *the compression at the lower end is*

$$W \cos \theta + \tfrac{1}{2} W \operatorname{tang} \theta \sin \theta = \frac{W}{2 \cos \theta}\left[2 \cos^2 \theta + \sin^2 \theta\right]$$
$$= \frac{W}{2 \cos \theta}\left[1 + \cos^2 \theta\right] \quad (11.)$$

2. *At the upper end* $x = 0$, and 10 becomes

$$\tfrac{1}{2} W \operatorname{tang} \theta \sin \theta = \frac{W}{2 \cos \theta} \sin^2 \theta = \tfrac{1}{2} W \sec \theta \sin^2 \theta. \quad (12.)$$

3. If the rafter is vertical, $\theta = 0$, and (10) becomes

$$L + L^1 = w x,$$

which at the upper end is zero for $x = 0$,

as it should, and at the lower end it becomes

$$w \, x \, A \, B = \dot{W},$$

as it should, since the total load rests upon it.

4. At the middle $x = \frac{1}{2} l$, and (10) becomes

$$L + L' = \tfrac{1}{2} W [\cos \theta + \operatorname{tang} \theta \sin \theta] =$$

$$\frac{W}{2 \cos \theta} = \tfrac{1}{2} W \sec \theta. \quad . \quad . \quad (13.)$$

5. If the rafter is horizontal $\theta = 90°$, and (10) becomes

$$L + L' = 0 + \alpha,$$

from which it appears that the compression due directly to the loading is zero; and that due to the resultant horizontal thrust is α, as it should be in order to support the weight.

Having deduced, as we believe, the correct formulæ for this case, it will be easy to test the correctness of the formulæ which are deduced by others.

Prof. Rankine, in the reference made above, leaves us to infer that the longitudinal compression will be uniform throughout, and finds its value by assuming that one half the load is supported at each end of the rafter. In this way we readily find that the strain would be

$$\tfrac{1}{2} W \sec \theta$$

which compared with (12), (13) and (11) shows that it is too great at the upper end, correct at the middle, and too small at the lower end. If the rafter is vertical the above expression gives $\frac{1}{2}$ W for the compression, whereas it should be zero, and at the lower end it is only half enough. The horizontal thrust at the upper end, by this method is $\frac{1}{2}$ W tang θ, which is the same equation (8).

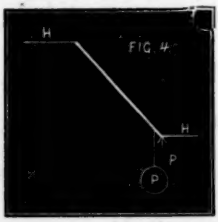
Trautwine considers that the total pressure at the foot of the rafter is a vertical force producing compression. This resolved horizontally and obliquely gives

$$H = W \operatorname{tang} \theta$$
$$L + L' = W \sec \theta$$

both of which are double the value given by Prof. Rankine, and the former is double the correct value.

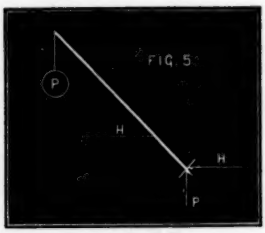
This method at first appears so plausible, that it may be advisable to show its fallacy by an illustration.

If P is very near the lower end of the rafter, as in Fig. 4, it is evident that H will be small, while the reaction is still equal to P; and if the weight P is exactly over the support it will develop no horizontal thrust, but in all these cases, according to Trautwine's formula, the horizontal thrust is the same. The longitudinal compression due to P *directly* is



constant for all positions of P for the same inclination of the rafter, and is P cos θ; but the compression due to H is dependent upon the position of P, being small when P is near B. Observe that P may be constant and H may have all possible values depending upon the position of P.

If P is considerably above H, as in Fig. 5, the lower end still sustains P and the horizontal thrust greatly exceeds that in Fig. 4. The compression in this case due to P is the same as in the preceding case, while that due to H greatly exceeds that in the preceding case.



It is worthy of note that the strains in this rafter are independent of the inclination of the rafter, brace, or beam, which holds its upper end in any practised case, *provided* that the two *rest against* each other.

But these illustrations only show the general fact by passing so near the limits of the problem as to make the result appear absurd, but I think they will make the following solution more easily understood. The seat of Mr. Trautwine's error consists in assuming that *the resultant of the two forces at the foot of the rafter is in the direction of the rafter.* This hypothesis is true only when the weight rests upon the upper end of the rafter. The true direction of the result-

ant may be found geometrically as follows:

Let P, Fig. 6, be applied at any point, then since H and P are in equilibrium about B, the resultant of P and H must pass through that point. It must also pass through the point *a*, where their line of directions meet. Hence *a* B is the direction of the resultant. If this resultant

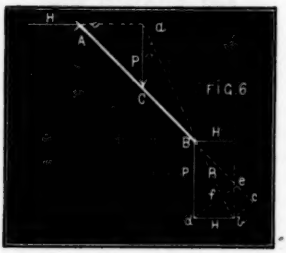


FIG. 6

be resolved parallel to and perpendicular to the direction of the rafter, the former will give the compression between C and B, due to H and P. We have from equation (1) $H = n\,P\,\text{tang}\,\theta$, hence the resultant,

$$R = \sqrt{H^2 + P^2} = P\sqrt{n^2\,\text{tang}^2\,\theta + 1} = \frac{P}{\cos\theta}\sqrt{n^2\sin^2\theta + \cos^2\theta}.$$

To resolve this multiply it by the cos of *b* B *c*. Erect *d e* and *b c* perpendicular to B *c*, and *b f* perpendi.uler to *d e*. Call B *d* = 1, then from,

$$d\,b = n\,\text{tang}\,\theta$$
$$d\,B\,c = \theta = f\,d\,b,$$

$$\therefore b\,B = \sqrt{n^2\,\text{tang}^2\,\theta + 1}$$
$$B\,e = \cos\theta, \text{ and}$$
$$f\,b = e\,c = n\,\text{tang}\,\theta\sin\theta.$$
$$\therefore B\,c = n\,\text{tang}\,\theta\sin\theta + \cos\theta. \text{ and}$$
$$\cos b\,B\,c = \frac{n\,\text{tang}\,\theta\sin\theta + \cos\theta}{\sqrt{n^2\,\text{tang}^2\,\theta + 1}} = \frac{n\sin^2\theta + \cos^2\theta}{\sqrt{n^2\sin^2\theta + \cos^2\theta}}$$

The last expression is found by multiplying the terms of the preceding fraction by cos θ.

The total compressive force is found by multiplying the value of R given above, by the cos of *b* B *c* as just found. This gives

$$\text{Compression} = \frac{P}{\cos\theta}\sqrt{n^2\sin^2 + \cos} \times \frac{n\sin^2\theta + \cos^2\theta}{\sqrt{n^2\sin^2\theta + \cos^2\theta}} = \frac{P}{\cos\theta}\left[n\sin^2\theta + \cos\theta\right]$$

which is the same as equation (6).

If the rafter is uniformly loaded the resultant of the load would pass through the centre of the rafter. Calling the load W and proceeding in the same way as above, we find for the *resultant compression at* B

$$\frac{W}{\cos\theta}\left[\tfrac{1}{2}\sin^2\theta\cos^2\theta\right] = \frac{W}{2\cos\theta}\left[\sin^2\theta + 2\cos\theta\right]$$

which is the same as equation (11.)

The compression at any point may be formed in the same way by considering the resultant of the weight between A and the point.

ON THE CYLINDERS FOR THE ALBERT BRIDGE.*

After some introductory remarks, Mr. Kingsford described the general *modus operandi* of ordinary loam-casting in a foundry, that being the method by which the cylinders for the Albert Bridge are being produced. As this will be familiar to most of our civil engineering readers, and as our space is limited, we pass on to give the substance of the immediate subject of the paper. In the arrangement of the piers, as originally designed by the engineer, Mr. Ordish, it was intended to build up the external casings with cast-iron flanged plates, bolted together in cylinders, the piers when complete to be filled up with concrete. The lower portion of each pier was to be 21 ft. in diameter for the first 9 ft. in height, and from thence the piers were to be contracted to 15 ft. diameter by means of tapering plates for another 9 ft., and from thence to the roadway the piers were to have a diameter of 15 ft. The circumference of the lower part was to have been cast in 12 segments, each plate to be 9 ft. high; the upper parts of the piers in 8 segments; all the flanges, both vertical and horizontal, were to be bolted together and caulked. Plates of these dimensions require to be cast with great care in order to keep them from buckling in cool-

* From a paper read before the Civil and Mechanical Engineers' Society, by Mr. C. KINGSFORD.

ing, otherwise a great deal of labor is wasted in chipping and adjusting them to bring in the bolt-holes, and this would have to be done in the river, causing great delay and expense. It would have been impracticable to transport such large castings as 21 ft. cylinders from the country, but the Battersea Foundry being situated so close to the proposed bridge, Mr. Kingsford thought it quite feasible to attempt to cast them in rings or cylinders in loam, instead of in plates as at first proposed, and he mentioned it to Mr. Ordish, who agreed that it would be preferable if practicable. Before undertaking, however, such large castings, there were several very essential points to be considered. The foundry at Battersea is 150 ft. long by 75 ft. wide ; the portion specially set apart for loam work is traversed by a travelling crane of 30 ft. span, carried by the external wall on one side and by a row of columns and girders running down the centre of the foundry on the other. The cupolas (3 in number) are situated at the end of the traveller's run. The only available portion of the loam ground that could be set apart for the purpose of casting these cylinders was about 80 ft. by 30 ft. under the traveller, as none of the cranes would be powerful enough to lift such heavy cores and castings. The space necessary to build the cope for the 21 ft. cylinders would be at least 30 ft., and nearly the same for the core ; thus 60 ft. of the 80 ft. would be disposed of, leaving only 20 ft. for the 15 ft. cylinders. It was neccesary, therefore, to arrange for casting them alternately, building first a 21 ft. core, and then a 15 ft. core in the same ground, thus economizing space. The next point for consideration was how to get the castings out of the foundry, as it was quite evident at a glance that they must be got out on edge, as the doors were only 15 ft. wide, and could not be widened without endangering the superstructure. There was sufficient height, fortunately, to enable them to be lifted clear of the ground in this position, and rolling them down to the water's edge suggested itself as the best mode of delivery. These questions ascertained and settled, Mr. Kingsford's suggestion, that the piers should be cast in cylinders instead of in plates, was adopted. The production of such large castings is in reality a matter for the civil engineer quite as much as for the founder, for whereas in most cases the foreman at the foundry is left pretty much to his own resources and ingenuity to construct as he pleases his own tools and appliances, in this case it was not necessary for the engineer to aid him in well defining and reducing to accurate calculation the several strains likely to be met with and provided against in the construction of the mould, and the whole was thoroughly digested and laid down on paper before commencing the work. In spite of all these precautions, however, the strength required was underestimated, for the first cast was a failure, the brickwork in the core being too weak and giving way to the pressure of the metal. It was feared that the traveller was of insufficient power to carry a core of the size required with a wall of brickwork 9 in. thick, and which, it was calculated, would weigh, with the necessary iron in it, very nearly 18 tons ; so the core was made of 4½ in. work, with piers about 5 ft. apart, and its weight did not much exceed 10 tons. Every other detail appeared to be satisfactory. It was necessary to provide against the pressure of the metal on the walls of the cope; the cope was therefore built in the ground, of 9-in. brickwork, well rammed up all round to the level of the surface; for although the core had to be broken down for each casting, the cope, as far as the brickwork was concerned, remained permanent, and served for all the succeeding castings of the same form and size. When the pit was dug the loam-ring was laid in position, and upon this the wall was built. These rings were generally cast in one piece, but, for want of space in the foundry at the time, the ring was made in three segments, and bolted together ; and as it was proposed to cast the conical cylinders in the same pit, a strong cast-iron cross was provided, and laid permanently at the bottom of the pit, with its twelve arms passing under the loam-ring, so that it could be used to bolt down the conical cores without interfering with the cope of the first cylinders. The loam-ring for the cope was 18 in. wide and 2½ in. thick, and cast with twelve lugs round the circumference, to which lugs were attached the tying-down bolts, consisting of 1½ in. round rods, forged with stirrups fitting the lugs

of the loam-ring. The weight of metal in the ring and cross amounts to about 7 tons. The cope was built up of 9 in. brickwork, with binding plates set in the joints at about every 6 courses. The plates were $\frac{3}{4}$ in. thick, and 9 in wide; the walls were well rammed up all round and thoroughly dried. Thus far the structure is permanent, and remains *in situ*. The walls are faced inside with a coat of loam struck up in the ordinary way by means of the loam-boards; these, however, from their extra weight and size, required to be counter-balanced, otherwise the process differs in no way from the general plan adopted in all like cases. In striking up the cope a seating of about 6 in. in depth is formed at the bottom of the mould; a similar seating called a dummy is also formed on the floor where the core is to be built up; this seating serves for all the succeeding cores; the core being constructed on this dummy, corresponds exactly with the seating at the bottom of the cope, and when placed in position is guided by it into the centre, leaving the desired space all round for the metal. The core is made on a ring cast rather smaller than the seating, with 8 wrought-iron loops cast in, by which the whole is lifted and placed in the cope; upon this ring are 8 segmental plates, which carry the brickwork. These plates are clamped together, forming one ring, but as soon as the casting is made the clamps are knocked away, and the plates set free to allow for the contraction of the metal in cooling. At every 6 courses in the wall are binding plates in segments to strengthen the work, and the brickwork is 9 in. thick all over. The core thus constructed weighs 18 tons. In the first or lowest cylinder a curved moulding is formed on the bottom edge, for as no flange is here required it was thought advisable to strengthen the edge which bears on the ground and carries the weight of the superstructure; and at the same time something of the sort was required to equalize the metal, so as to avoid the chance of a fracture from any irregularity in the cooling. All these cylinders, it must be stated, are cast the reverse way to the position in which they will stand in the piers, in order that they may be relieved from the mould without breaking down the cope. The covering plate, which is cast in three segments, is struck up to the form of the bottom moulding of the cylinders; this, from their being reversed in the mould, being at the top, it corresponds with and fits into a seating formed on the top of the cope, and is cast with 33 holes, 30 of which serve for the runners, and 3 for the risers. These segments were capable of being dried in the stoves; but in order to dry the rest of the work, "portable kettles," as they are called, are employed; in these, gas-coke is burnt, and of course this is not so economical as drying in stoves; but the stoves at the Battersea Foundry will not take in a mould more than 14 ft. wide. When the bricks and loam are dry, the face of the mould is blacked, and then again dried, and the mould is then put together. A cast-iron cross having 12 arms is laid over all, and tied down by the 12 $1\frac{1}{4}$ in. bolts surrounding the cope. In making up the mould a sow or trough is formed, composed of sand and confined between two rows of jointed plates, called cribs, fixed on edge all round the top of the mould. In this sow are 30 runners of about $1\frac{1}{4}$ in. diameter, leading perpendicularly through the holes in the covering plate down into the mould between the cope and core. Three other holes of similar size, which serve as risers, are stopped off from the runners on the one side of the mould. Three basins communicating with the sow are formed to receive first the metal from the ladles. The metal when poured is thus conducted into the mould in 30 small streams, which insures a uniform flow to all parts at once.

The calculated weight of the casting is about 9 tons, but as it is always desirable to have metal enough, and to spare, it is run from 3 ladles, a 6 ton, a 4 ton, and a 3 ton, making in all about 13 tons of metal. The arrangement adopted of pouring the metal out at 3 founts is very satisfactory. The largest ladle is served by the traveller, and the other 2 by the cranes, one being close to the work, and the other about 12 ft. off, from which the metal flows to the mould along a trough. The metal is melted in 2 cupolas, one 3 ft. internal diameter, and the other 2 ft. 6 in. The largest cupola has 3 tuyeres, the smaller one 2. A pressure of 7 in. of blast was got with one of Lloyd's 30 in. fans, driven by an 8-horse engine, and the 13 tons of metal was run down in

about an hour and a half. A mixture of ¼ pig iron and ¾ best machine scrap is employed, which produces a metal extremely strong and suitable for the purpose.

The conical castings forming that portion of the piers of the bridge which reduces the diameter from 21 ft. to 15 ft. require rather a different arrangement with regard to the building-up of the core. The angle of the cone is so great, contracting as the cylinders do 3 ft. on each side in a height of 4 ft. 6 in., that it would be impracticable to lay on the loam overhead, as it were; it would not have adhered to the brickwork, but would have fallen off as soon as the board left it. The plan was therefore adopted in thicknessing up the cope and building the core within it. The cope of the conical cylinders is built inside that of the parallel ones, as there are some more to cast after these are done. When the cope is struck up in loam and dried, a thickness of wet sand, corresponding with the thickness of the casting, is laid on and struck up with the core-board and dried. The core is then built inside the cope, and when dry is lifted out and dressed, and the thickness of sand removed; in all other respects the casting is conducted as usual, except that as these castings present more surface on plan, they require extra holding down, which was effected by means of cast-iron clamps on the inside, in addition to the 12 external tie-bolts. The 15 ft. cylinders are made in every respect in a similar way to the 21 ft. ones, allowance being made for the difference in size only. They weigh only about 7 tons, and it takes a week to prepare each mould.

Mr. Kingsford concluded his paper by some remarks on the estimation of the several strains that are set up in moulds during the time of pouring in the metal for these large castings. In the case of the 21 ft. cylinders the width of the flange was 4 in., the circumference being 66 ft., giving an area of 22 sq. ft., multiplied by 4 ft. 6 in., the height of the cylinder; this equals 99 cubic ft. of displacement, and as a cubic foot of iron weighs 4 cwt. there is about 20 tons exerting itself to lift the core. In the conical castings the flotation is considerably more. The difference of areas between the cylinder at the bottom and top of the mould represents about 190 sq. ft.; this, multiplied by 4 ft. 6 in., the height, gives 855 cubic ft. of displacement, being equal to 170 tons. From this we must deduct about 20 tons for the weight of the core, which represents a vessel floating in liquid iron, and 150 tons is the upward pressure on the tying-down bolts. There are 12 1¼ in. bolts, equal to 27 circular in., 10 tons to a circular in. being generally considered safe. This gives 270 tons, which should be sufficient; but in order to be on the safe side, the mould is clamped on the inside, which greatly adds to its rigidity, the object being to guard against the mould straining, as much as possible. Besides the actual strain from the pressure of the metal exerted to float the core, there is the lateral pressure on the walls of the core and cope. The cope being in the ground and well rammed up, may be passed by as safe, but the core requires very careful construction. Eight of these cylinders, out of about 30, have been cast. The core of the first, as before stated, was not sufficiently strong enough to bear the weight of the metal against its sides, and it gave way. The second strained so much that instead of its thickness averaging 1⅜ in., as it ought to have done, it averages 2 in., and weighs 12 tons. The succeeding ones have not strained much, but the lightest is fully ⅛ in. thicker than it ought to be, and Mr. Kingsford believed that, in order to cast them without straining in the least, the walls of the core would have to be 18 in. thick, and the core would weigh upwards of 30 tons.

Now that it is possible from practice, however, to judge the amount of the strain in the castings, it was allowed for, and the remaining cylinders will be nearly correct as to thickness. Another cause of straining is the pressure of the suddenly heated air in the mould as soon as the melted iron is run in. This is not so easily calculated; but it is necessary, in order to have a good sound casting, free from scabs, that the air should be thus confined. The metal enters by 30 runners, and the same quantity of air, greatly augmented in bulk, has to escape through 3 risers, which it does, in all probability, at a pressure of nearly 15 lbs. to 1 in. If so, it would just about double all the strains, for 1 in. of iron, 4 ft. 6 in. high, equals about 14 tons or 15 tons.

ARCHITECTURE FOR ENGINEERS.*

After some introductory observations, Mr. Rew remarked that the right understanding of the principles of architecture by engineers was of the greatest and most varied consequence and value. That English engineers had carried out works of great value and importance in almost every country in the world was a fact to be proud of, and while it was to be hoped that great works, even surpassing those that had been accomplished, were yet to be achieved by them, it was to be trusted that such future works might approach as near to the artistic beauty as the past ones did to scientific and mechanical perfection. Up to the present, if our mechanical architecture had been bad, our "engineering" architecture (if the expression might be used) had not been all that could be desired. Some of the railway bridges over the Thames, for instance, did not convey the idea of abstract and perfect beauty, while the preposterous roofs of our great terminal railway stations seemed first of all to suggest "how much you are in the open air when standing on the platforms under them." It seemed ridiculous to build such enormous roofs where headway was only wanted for the funnels of the locomotives. If it were argued that, to cover so great an area with a roof of one span, such a great height was a necessity, and that to divide the same area into portions by rows of columns was bad economy of space, it might be said, in reply, that admitting the argument of economy (which was, however, an open question), the gain of a little more space in the platforms was very dearly bought by the frightful appearance of these large roofs from the outside. As for bridges, Mr. Rew feared that until the time came, when engineers should turn their attention to building them of stone again, or at least until stone piers took the place of iron cylinders, papers on "architecture for engineers," would at least be premature; for, anything more utterly above or below careful criticism than structures with no more artistic beauty than the Chatham and Dover Bridge at Blackfriars, or the South Eastern Bridge at Charing-cross, it would be difficult to imagine. In the new Blackfriars Bridge there was at least one great step in the right direction—viz., the adoption of piers of masonry, instead of the ill-proportioned and dropsical iron columns seen in the railway bridges mentioned. But even in Blackfriars bridge the columns (or pulpits) standing on the cutwaters offended against the first law of good architecture—the law of Truth. Why those columns should be of their present diameter, with only a light parapet to carry, it would puzzle the architect, if not the engineer, to tell. Another, but smaller fault, was the absence of a moulding of some sort or other under the brackets or trusses to the cornice of the bridge; as they now were, they appeared to be supported by the very part they were meant to strengthen. These were examples which went to show that there were many points where great improvement was possible. It was, therefore, worth while to try to discover some of the simple (but too often neglected) principles in the application of which good architecture consisted, and to the application and understanding of which any improvement æstheticially of our engineering works (if it was to be made at all) must be mainly due. The subject would be better appreciated by starting with a clear understanding of what was really meant by the word "architecture" as distinguished from "building," for the things meant were quite distinct from, although often associated with, each other. It was quite possible to have a building covering a large area, yet quite innocent of anything that could be called architecture. The building, so to speak, was the constructed skeleton; the architecture was that which determined the exact outward appearance of the perfect body. To build was literally to erect or construct—to fit and apply each material in the form and position most suited to its capabilities and nature, and so as to get the most work out of the smallest quantity of material; but, in the words of a modern writer, "building does not become architecture merely by the stability of what it erects, and it is no more architecture which raises a church, or fits it to receive and contain with comfort a required number of persons occupied in certain religious offices, than it is architecture which makes a carriage commodious or a

*A paper read before the Civil and Mechanical Engineers' Society by Mr. C. H. Rew.

ship swift. That is church-building, coach-building, or ship-building, as the case may be, but it is not necessarily architecture." It had been well said that architecture was "the adding of unnecessary features to a building." For instance, if a stone bastion were erected—that was building; but if a projecting course of masonry was left near the copping, and caused to represent a cable—that was architecture. Or if an arch was thrown over a door or window opening—that was building; but if the arch stones were moulded or carved, that moulding and carving was architecture. Therefore, while there could not possibly be architecture without building (or, for that matter, *good* architecture without *good* building), it was quite possible to have building in which architecture was wholly wanting. Among the leading principles which distinguished good from bad, whether in architecture or building, firstly, and at the head of all, came the law of common-sense, or Truth. When this was wanting the building or architecture in question must be bad—utterly past amendment. No architecture or building which was a sham was worth anything but contempt. But if, on the contrary, having regard to the fundamental law of truth, a building was first of all planned, with each portion or room in its natural place, and where, from its intended use or connection with other parts, one would expect to find it, much had been done towards obtaining a good building. If the walls were solid and good, the doors and windows, and other subordinate parts, so grouped and placed as to weaken the walls in the least degree possible, another step had been taken in the right direction. If the roof was arranged to cover the building in the simplest and least complicated way, instead of, as was sometimes done, making it as elaborate and eccentric as possible, as if the designer had taken delight in getting into little dilemmas just to show how clever he was in getting out of them, still further was done in the right direction. And if the eaves were brought well over the walls, and the chimneys carried well above the roof, the designer would be rather a genius than otherwise if the result was not something in the shape of a good building. Again, the subject might be yet further gone into by considering the use and nature of the materials employed. As regarded stone, as stone, the geological arrangement of the rocks was the surest guide to the right arrangement of the stone in the different stories of a building. Granite, which (speaking geologically) was the lowest or base stratum or system, naturally suggested itself as most appropriate in the lower stages of a building, or in any portion where great weight had to be sustained. As for the working of the individual blocks, the safest rule was to use the stone as soon as it was worked to the required shape, for whatever was done more was just so much ruination to it. In nine cases out of ten more labor was wasted in what was called "finishing" stonework than was spent or required to be spent in working it to the required form. People wondered why modern stonework looked so tame and lifeless. Writer after writer had pointed out that in the old masonry the stonework was "rough and ready;" yet in practice, they would not be content with having stonework wrought into shape or *done*, but over and above that, it must be finished. And most thoroughly finished it was, so far as having any life or beauty left in it. As an instance, during the rebuilding of St. George's Church, Doncaster (one of the first in point of time, as well as of merit, of modern attempts at restoration), an argument was in progress between some members of the Restoration Committee, during a visit to the masons' yard, as to why the new stonework persisted in looking so tame, although the masons were working it as nearly as they could to the old sections. Nobody could tell until one of the committee happened to see a piece of moulding lying on a block. That, they all exclaimed, was exactly what they wanted, but they were corrected by the mason saying, in a tone of pitying condescension, that it wasn't "finished." That explained the whole secret, and no more "finishing" was allowed, the result being all that could be wished. Again, in the use of brick, the rule at the bottom of it all (and the infringement of which caused a very large proportion of architectural failures) was to "let a building look as if it was a brick building, and not a stone one." Brick, if rightly used, was as honorable a building material as stone, and quite as much (if not more) capable of being its own decoration. In London, brick, according to the doctrine of locality, was the right ma-

terial to use, and was strictly speaking, "the indigenous building-stone of the neighborhood." As instances of what could be done in brick architecture, Mr. Rew referred to the buildings on the east side of King's Bench-walk, in the Temple, and (of modern work) the small church of St. James's the Less, and the more ornate one of All Saints', Margaret street. Among the ways in which brick was misused was that of attempting, by grouping the courses, to give the idea of large blocks of stone. This was sometimes done by setting back every seventh course or so from the ordinary plane of the walls, the intention being to convey the idea that the six courses formed a single course of stone, and that the seventh was the joint. The same thing might be done by placing at regular intervals a double course of chamfered bricks. Another and very common thing was to see the wall built of one kind of bricks, and the jambs and quoins of another. All such proceedings were directly opposed to the fundamental rule of truth and common-sense, for, taking the last example of the quoins, the mistake was not in putting the better material where there was more work to do or more exposure to bear, but in making it pretend to be what it was not. Just in the same way that in masonry one sort of stone was used for the ordinary walling and a harder and better kind for the quoins, where the means at disposal would not allow the better stone only to be used, so, in brickwork, it was perfectly rational to use an inferior sample of brick in the walls, with a harder and firmer kind for quoins. But doing this honestly was a different thing to building quoins of brick that looked at a little distance as if they were stone, if bad and false. It seemed to the author that it might be taken as an axiom, that the first step towards the right use of brick as a building material was to put utterly out of mind the notion that brick was *only* to be regarded as a cheap and nasty substitute for stone, and only to be tolerated where the funds at disposal would not admit of the latter material. He did not, however, object to the use of brick and stone in the same building, for, of course, there were portions, such as columns, with their bases and capitals, brackets, corbels, and, in fact, all parts meant ultimately to be moulded or carved, for which stone was the only suitable material; but they should show at once, by their position and use, that they had a reason for being of stone, and should not leave room for the idea that it was a mere freak or question of the moment with their designer as to which they should be. Of timber and iron there was not so much to be said as at first sight appeared. As regarded timber, its use was becoming almost a thing of the past, so that there were not so many chances of making mistakes as its more frequent use would afford. As the subject of ironwork was exhaustively treated of in a paper read before the Society last session by Mr. Driver, he (Mr. Rew) need not dwell on that subject on the present occasion.

As to the artistic part of his subject, Mr. Rew said that the first great characteristic which should be kept in view was what was meant and understood by the term "proportion." In order to attain this, it was necessary, according to Mr. Ruskin, to have one large thing and several smaller things, or one principal thing and several inferior things, and to bind them well together. "Sometimes," said Mr. Ruskin, "there may be a regular gradation as between the height of stories in good designs for houses—sometimes a monarch with a lowly train, as in a spire with its pinnacles—the varieties of the arrangement are infinite; the law is universal. Have one thing above the rest, either by size, or office, or interest, and the rest subordinate to it as their relative size or office demands, or anything like proportion is an impossibility." Another sure sign of good architecture was change or variety—*i. e.*, designing each portion, wall, roof, arch, door, or window, with care and study, suiting its form, size, and decoration to its use and office in the building, thinking no part too mean to be deserving of the architect's best work, and as far as possible removed from the more generally accepted principle of making one detail drawing do for as many duplicates as possible—an arrangement of evident advantage in taking out quantities, but as evidently fatal to the architecture of a building. The work of the artist-architect should bear at every point traces and proof of the pleasure caused in the process of designing it. There was one class of buildings, of the first importance to engineers, that, according to Mr. Ruskin, should never be decorated at all, but

should be wholly devoid of anything like ornament. Why this sort of argument, however, should apply to railway stations more than to other buildings where business had to be transacted, it was difficult to discover. The next great consideration in obtaining effect in architecture was that of shadow and shade. On the right application of this law depended almost wholly the effect and explanation of grouping. The "power" of architecture depended almost entirely on the breadth and depth of its shadows. A walk round the cloisters of Westminster Abbey on any bright summer afternoon would show how much their effect depended on the broad masses of clearly-defined shadow. The foregoing were some of the guiding rules which conduced to the attainment of good architectural effect, but, as he had stated, the first great essential was common sense, or truth, meaning thereby the absence of anything approaching either to affectation or deceit—and this in the quality or nature of the material no less than in the amount of labor bestowed upon the work. "We may not," to again quote Mr. Ruskin, "be able to command good or beautiful, or inventive architecture, but we can command, at least, honest architecture. The meagreness of poverty may be pardoned, the sternness of utility respected, but what is there but scorn for the meanness of deception?" Never to gain effect or to make work look quaint should this "meanness of deception" be resorted to; never to suggest a mode of structure other than the true one; and the surface of one material should never be painted to imitate the surface of another. If marble chimney pieces could not be afforded, be content with stone, slate, or wood, but do not paint them to represent marble. In the case of woodwork, if mahogany or walnut could not be afforded, be content with deal, only let it suffice to varnish it, or paint it some inoffensive flat color, instead of making people believe it was maple or wainscot oak by the use of the abomination known as graining. This principle of honesty was to be shown in many other ways, notably in the application of enrichments or decorations to returned or partially hidden surfaces. In parts of a building bearing ornament, it was not good architecture to stop it in portions only partially seen, unless some bold and openly confessed termination was put, telling the spectator plainly that it did not stop, and not leading him to suppose that even the less prominent parts of the composition had been decorated.

To have good architecture, one must start with all the circumstances and requirements of the building in view. For instance, this window or that door demanded, from its relative importance, a certain amount of architectural treatment, which should be given it, not so much regarding its actual position in the building as the dignity of the functions it had to fulfil. This rule also applied to the "members" or component parts of the ornament, and we might always estimate its lasting value by the amount of rightly directed labor spent upon it—for it was sympathetic labor that alone gave worth to ornament of any kind. There should be no decoration at all unless it could be had good, and to have it so time and skill must be expended upon it. Any attempt to reproduce ornament cheaply, and by means other than labor and thought honestly bestowed, was to be avoided wherever good architecture was required. A building might be ever so plain, and yet its architecture might be good in the highest sense of the word. Salisbury Cathedral was much nobler architecture than Henry VII.'s Chapel or the new Palace of Westminster, although the one was almost as devoid of ornament as the others were smothered with it. It might be safely taken as a principle that those portions of a building that derived the most interest from their form were those that could best do without superadded decoration. In the case of a series of pointed arches, for instance, it would be much better to let the arches depend for their interest on the curves to which they were struck, and to put such decoration as was at command into the otherwise rather uninteresting spandrel, than to have an elaborately moulded and parti-colored arch, and a perfectly dull and monotonous surface in the spandrel. The common practice, too, of having the capitals of columns so elaborately carved, in many cases where everything was plain, was a very great mistake. Given, then, all these tests of good architecture, in what style were to be found the largest number of them to put to ordinary use? His answer was

our own English Gothic. Discarding copyism after a careful study and attempt to discover the principles of common sense and mechanical science in construction, and the correct application of ornament, architects should carry them out in their own work and practice. English architecture was the fitting companion and accompaniment of English engineering, and would be all the more so as it consisted of and rested upon that constructive science in the application of materials ready to hand, which was the very essence of engineering.

THE PRESERVATION OF IRON SURFACES.

From "The Engineer."

Although it might be injudicious to pass comments on the Megæra case, *per se*, whilst yet the investigation is going on, yet in so far as testimony bears upon the preservation of iron structures generally, we make no apology for offering some remarks suggested by revelations which have already been made. The agencies conducing to the disintegration of iron merit the fullest consideration. Some cases of wear and tear involve only questions of expense; of the wearing out of a substance renewable at a cost greater or less, no question of safety to life or limb coming upon the field of debate. A moment's consideration will make apparent the fact that the disintegration of some iron structures does not belong to this category. To begin with iron ships, for example, the Megæra calamity was not needed to impress the fact that on the oxidation or non-oxidation, the integrity or degeneration of a few square inches of an iron plate, the whole question of the safety or the perdition of a ship's crew turns. Take again, the case of tubular bridge constructions and iron suspension bridges, of which the two structures across the Menai Straits are prominent examples. Here it will be evident, on consideration, although the thought is alarmingly disquieting, that day by day they grow weaker, and that no means of effecting repairs, wholly reliable and satisfactory, are known to exist. Granting —and the postulate is not logically to be evaded—that the inferior limit of cohesion is slowly but surely approaching, there must come a time when a crash will occur—a catastrophe at the very thought of which the blood curdles. To ignore an inevitable result merely for the cause that reflection is disquieting, is the very reverse of practical common sense. Rather study conditions, making the best of unfavorable actualities, with the intent of providing in future against—more than contingencies—*certainties*, by the utilization of such aids as science has put within reach. For reasons that will be obvious without specifying them, we regard the preservation of iron ships as of less pressing import than that of suspension and tubular bridges. Whether a ship be of wood or of iron, its normal or calculated life is not great. Some 50 years, perhaps, may be fairly considered as a long term of existence. The times of possible calamity to a ship are comparatively short, viz., only from port to port; moreover, even though an iron bottom should give way and a leak occur, and further, no means of repairing the disintegration exist, the pumps are still a resource which, as we have seen in the case of the Megæra, may fairly be relied on to tide over the utter catastrophe of sinking and utter destruction. To our mind, the actuality of iron bridges, tubular and suspension, is far more serious. Whereas a ship is designed and constructed to last only a *short* time, a bridge, comparatively so to speak, is meant for *all* time. It behooves the engineer, then, to ponder well the elemental deteriorating forces which act upon the material of their construction. Chemically regarded, the relations of iron to external influences are not difficult to enunciate. This metal may be taken, for purposes of investigation, as presenting itself in the three states of actually pure iron, of impure though still malleable iron, and of cast iron, which latter, chemically speaking, is the metal in its major degree of impurity. For practical purposes, we may eliminate the first. Absolutely pure iron is a mere chemical curiosity, never occurring in practice, and not often met with in chemical laboratories of research. Ordinary wrought iron—

which is the metal in its highest state of practical purity—and cast iron, are the only forms with which we have to concern ourselves in any investigations relative to protecting the metal against external agencies. Now the fact may be taken as proved, that if iron be absolutely protected against external agencies, it is, chemically speaking, indestructible. We concede that though one of many circumstances, prolonged vibration being of the number, iron may assume a new molecular state, a state more or less crystalline, in point of fact, whereby its cohesion is weakened. Fortunately, however, this result in practice is found to be rare, more rare, indeed, than either theory or laboratory experiments would seem to promise. Whether rare or frequent, the condition is one that holds out no hope of amelioration, and hence the engineer must be content to accept it as an integral fault and drawback—a negative quantity in the summation of the qualities of an indispensable metal. To internal, molecular, or mechanical causes of iron weakness, we do not propose to give attention just now, only summarizing the chemical conditions which affect iron externally. What engineering practice requires is some material which, superimposed upon iron, wrought or cast, shall screen it from the elements, for all time if possible. Now in supplying an indication or hint, an iron casting, if thoroughly studied, is expressive. The circumstance must have come home to the apprehension of every observant engineer that an iron casting if taken from the mould, and neither filed nor otherwise abraded, may be exposed to air and moisture for long periods with hardly any effect. If filed, however, planed, or otherwise disintegrated, then it is found that on the parts so meddled with, the elements work corrosion proportionate to their kind and their degree of concentration. Pursuing investigation, it will be found that the immunity depends upon a superficial glaze, readily discriminated as the silicate of iron. This casualty points to the artificial use of some sort of silica glaze for the preservation of iron surfaces both wrought and cast; but, unfortunately, except in very rare instances, the artificial use of any such silica glaze is impossible. Many attempts to employ silica have been made, using this material in the condition of soluble glass. These experiments have been invariably unsuccessful, and for very sufficient reasons. Except the silica glaze could be laid on by some igneous process, the probabilities of duration would be against it. The very circumstance of the glass being soluble affords a strong presumptive reason that it, under natural conditions, should in the end wash away. Accordingly we have never seen any sort of artificial silica glaze which fulfils the indication desired, and we have no belief that further experiments in this direction will accomplish what past experiments have failed to achieve.

Before further investigating the qualities of other iron surface coverings, it will be well to pass under consideration the merits of the so-called galvanizing process, otherwise the covering of a surface of iron with a thin surface of zinc. This process is known to be very efficient up to a certain point when applicable, but a zinc covering, however thick, will not protect iron in perpetuity, as is sometimes erroneously imagined. The science of zinc covering is very ill apprehended, though its principles and practice can be easily set forth. It is a law that when two metals come in contact, one of which is more easily acted upon than the other, the metal of naturally lesser destructibility is wholly protected so long as a competent amount of the other metal remains to be sacrificed. The result will wholly depend on the nature of the metals used. If the metallic couple be lead and iron, then it is the latter which suffers, as we find when iron street palings are fitted to their sockets with lead. The pairing of copper with iron is still more destructive to the iron, hence the well-known impossibility of copper sheathing the bottom of an iron ship. Tin and iron constitute another metallic couple in which iron is the metal sacrificed, as we constantly see in the example of tin plate. Here, so long as the tin surface actually remains intact, of course the underlying iron is hermetically sealed, and no chemical effect can happen ; but so soon as the tin is disintegrated, exposing the iron, then the latter perishes much faster than had there been no tin at all. The coupling of zinc with iron so completely reverses voltaic conditions that the zinc alone suffers, and even when the zinc is all oxidized the resulting oxide constitutes a mechanical

protection of no small efficiency. The so-called galvanization of iron, then, although efficient up to a certain point when applicable, is under so great a variety of circumstances inapplicable, that a competent and generally available mode of protection has still to be sought. In the investigation of this we come to the divers category of paints, by whatever name designated. These have to be considered in reference to the two points of vehicle and pigment, both of which have to be taken count of. Amongst the most frequent of pigments is lead oxide in one of its many varieties, but we venture to affirm that no one pigmentary matter for iron surfaces can have so many powerful objections alleged against it from the side of theory, or a heavier inculpation from the records of practice. As a supposed protection to the bottom of iron ships, lead oxide least well responds to the result intended. The fact has been conclusively proved that, under the condition of immersion in sea water, lead oxide paint laid upon an iron surface is prone to be decomposed, and to evolve metallic lead, the effect of which has already been illustrated by the case of iron palings lead socketed. If experience be appealed to, as results have proved, there can be nothing more clearly indicated than the utter abandonment of lead oxide as a pigment for this class of work, no matter what the vehicle of incorporation may be. As a pigment or body color for iron surfaces, we believe that oxide of iron is, if not the best, the best available; but, as will presently be seen, we lean to the opinion that the very best protective paint, if paint it may be called, for the protection of iron, is marine glue, dissolved in the curious fluid cupro-ammonium. It may be either used alone or in combination with a certain percentage of white arsenic. This semi-fluid never blisters, not even when laid on hot surfaces; it dries in half an hour, and, so far as theory furnishes indication of futurity, it should be imperishable. There are some to whom the very sound of copper in connection with iron will come as an evil omen, but the alarm is misplaced. Whether a copper solution shall destroy iron or protect it, will depend wholly on the nature of the copper solution. For example, a solution of ordinary blue vitriol, or sulphate of copper, acts so rapidly on iron, that it may be even used instead of aquafortis for etching on iron or steel plate; but as for cupro-ammonium, a bright steel or iron surface, if immersed in this, *never rusts or otherwise tarnishes* so that a cupro-ammonium bath would perhaps be the best means known of protecting from rust delicate steel goods, such as surgical instruments.

Having treated thus much of the means of protecting iron surfaces from ravages of the elements, it may be well to particularize as to what those changes are. Oxidation is commonly but erroneously spoken of as though it were the only agent promoting the destruction of iron. This is so far from being the case, that both chlorine and sulphurous acid are far more disintegrating. Chlorine, however, so seldom is developed in air, that practically it may be left out of account; though as to ships' bottoms, the chlorine of chlorides in sea water has a wide sphere of practical destruction. Far otherwise is the case with regard to sulphurous acid, a gas which, associated with moisture, as it is, in railway tunnels, wreaks sad damage on all iron structures exposed to its influence. It may be well to remark also that, wherever sulphurous acid exists in any considerable quantity, the zinc surface of galvanized iron is no protection, the former metal undergoing solution so fast, when coming into contact with sulphurous acid and moisture, that *washing away bodily* is the fittest expression indicative of what happens under these circumstances.

A COMPENSATING COMPASS.

From "Engineering."

M. Arson, engineer to the Parisian Gas Company, has just invented a compensating apparatus for correcting the deviation of the compass. The needle of course does not in general indicate the position of the magnetic north. It is affected by the masses of iron entering into the construction, the armament, or the cargo of a ship. These deviations, which were very feeble in the time of wooden sailing vessels, have

become more and more considerable, in proportion as iron has been more largely used in the hulls of ships, as powerful engines and boilers have been introduced, as iron armor plates of ever-increasing thickness have been added to the sides of vessels, and as iron has been utilized for masts and rigging. There are cases where the magnetic influence of the ship so overbalances that of the earth, that although the position of the compass is chosen with the greatest care, it is impossible to obtain much information from its indications.

The means most generally employed to escape this inconvenience consist in checking the deviation of the needle by the influence of the ship, and preparing either tables of corrections or a curve, called Napier's curve, the inspection of which allows the deduction of the true from the observed variations. This estimation of deviation entails a rather long and delicate operation, which, moreover, has to be repeated for different latitudes, to allow for the alterations of magnetic influence.

The mathematical works of Poisson and of Airy have furnished, it is true, analyses of complicated magnetic phenomena, and many investigators have proposed means of compensating the deviating influences. But navigators have shown in general little confidence in these various systems, because all would require frequent changes in the position of the magnets, or of the masses of iron which serve for compensation; and these changes involve operations so delicate, and an incertitude so great, that it is preferred to put confidence in a compass which is supposed to be compensated, and which is more or less true.

The masses of iron in a ship act in two ways on the needle of the compass: first by their permanent magnetism, and then by the induced magnetism that they take under the influence of the earth. The first effect is constant, and comparatively easy to subdue. The second varies with the position of the ship, and can be compensated only by a movable needle.

The uncertainty of the moving compensators involves, in the port of departure, the correction of the deviation of the compass by a magnet as far as possible, then ascertaining by direct observations the remaining deviations, in order to place their quantity on the table or on the curves of correction. At present this is the general practice in the navy.

M. Arson hopes by his arrangement to obtain exact compensation. Fixed magnets compensate the deviations due to the permanent magnetism. Bundles of soft iron wire placed according to certain laws given by calculations, ought to compensate the deviations caused by induced magnetism in all positions of the ship and in all latitudes. The proposed apparatus, which has already been applied on one of the steamers of the Transatlantic Company, contains, besides the ordinary card, a second card, serving as an indicator. When it is wished to follow a given route, this latter card is traced by means of a wheel until it indicates the desired angle. Now by this movement the operator has placed the packets of soft iron into the position in which they are required to compensate for the deviation corresponding to the position of the ship. It is sufficient, then, to adjust the needle of the compass to the same angle which has been given, in order that the route indicated may be actually followed.

Conversely, if it be wished to ascertain at any moment the route which the ship follows, it can be done by moving the wheel before mentioned until the repeating circle indicates the same angle as the compass. By this movement the compensating parts will have been placed in the position which corresponds to the compensation in the azimuth where the vessel is; the angle observed will be the true angle of the route.

If the results sought can be obtained, they will be obviously invaluable. Seamen experienced in these difficult questions will be the best judges of the apparatus of M. Arson.

For the fabrication of an article called sponge paper, lately patented in France, evenly and finely divided sponge is added to ordinary paper pulp, and this is worked, as in the common paper making apparatus, into sheets of different thicknesses. It is said to have all the peculiarities of sponge, absorbing water readily, and remaining moist a long time. It has been used as dressing for wounds with considerable advantage, and is capable of several important technical applications.

ROYAL INSTITUTE OF BRITISH ARCHITECTS.*

THE BRIDGES OF LONDON.

After treating of the bridges of London historically, as connected with the varying circumstances of the metropolis in early and later times, the author proceeded to notice them simply as means of communication considered with reference to the localities on each side of the river, and to traffic as developed by increased population and trade. On this head he referred to the great difficulty now experienced on account of the great accumulation of business at theEast-end, considered in connection with the very large traffic on the river up to London Bridge. The two great traffics by land and water, as it were, overlap. Bridge communication, he pointed out, is much wanted in the neighborhood of the Tower ; the great river traffic, however, will not admit of interference below London Bridge, except at enormous cost. High level bridges have been proposed, a tunnel has been constructed, but still the traffic from the east of London Bridge comes to that crowded thoroughfare, and there is no immediate prospect of any change in that respect. Much has been said of late years as to the widening of London Bridge, but the difficulty was not so much on the bridge itself as in the approaches; the object should therefore be to divert traffic westward as much as possible. If it be determined to widen London Bridge, it should be done so as not on any account to interfere with the general elevation ; any addition by ironwork would be a barbarous proceeding, destroying the effect of one of the finest bridges in Europe ; besides, such addition to the bridge would not relieve its approaches, which are as objectionably crowded as the bridge itself ; moreover, as the foundations of the bridge would not admit of more weight being put upon them, this would be fatal to several plans which have been proposed. One suggestion for widening London Bridge, which has been for some time before the Bridge House Estates Committee, was shown by two plaster models exhibited by Mr. Carr; the proposal consists in thrusting the granite parapet somewhat over on to the cornices and to make it as thin as granite will admit of being worked and fixed in safety. The footpaths are now 9 ft. wide; the addition would be 2 ft. 6 in. on each side of the bridge, making the footpaths 11 ft. 6 in. wide. This plan Mr. Carr considered as the utmost that should be attempted. The great object, however, should be to lead the traffic westward to Southwark Bridge. The toll is now abolished, and Queen Victoria street on the one side and Southwark street on the other have opened up good approaches to that bridge; but great hindrances to its more extended usefulness are its steep approach and narrow width. To render this bridge capable of taking its due share of traffic, it is proposed to take down the existing cast iron arches, and to substitute arches of wrought iron; by this change of construction the thickness of arch and road material might be reduced from 9 ft. to 5 ft. 6 in. It is proposed also to reduce the headway underneath from 29 ft. 6 in. Trinity high water to 25 ft., making it the same as at the new Blackfriars Bridge. The summit level of the roadway would thus be lowered 8 ft., which would admit of the gradient on the south side being altered from 1 in 26 to 1 in 43, and on the north approach from 1 in 20 to 1 in 40—1 in 40 being the standard of good gradient fixed by the Bridge House Estates Committee for the new Blackfriars Bridge. In altering the arches it is proposed to corbel out the footpaths, increasing the width of the bridge from 42 ft. to 54 ft., thus making it the same as the present London Bridge. The nearest route from the Bank to the Elephant and Castle is over Southwark Bridge; if, therefore, the approaches were made good and the width of the bridge increased, it is felt that a considerable portion of the traffic now using London Bridge might be drawn westward to Southwark Bridge. Waterloo Bridge should be thrown open toll free, but there is very little prospect of this being done at present. The rebuilding of Westminster Bridge of a width of 84 ft. has provided ample accommodation there. It may be regretted, Mr. Carr thinks, that the inclination on this bridge itself has not been made a little steeper, in order

* A paper read before the Royal Institute of British Architects, by H. Carr, C. E.

to ease the approaches; the gradient on the bridge itself is 1 in 58, and the approaches 1 in 30 at the steepest part, whereas a general inclination of 1 in 43 would have been more advantageous for the road traffic, without interfering to any appreciable extent with the river traffic. The approaches have been somewhat sacrificed to the bridge, instead of the architect considering the whole as one work, and giving the best possible inclination throughout. Lambeth Bridge was built to meet a supposed want, but, singularly, little traffic passes over it. Vauxhall Bridge is in a good position, but the extension of the South Western Railway from Vauxhall to Waterloo Bridge, and lately the formation of the Southern embankment from Vauxhall to Westminster Bridge, have caused a very severe loss to the Company. Chelsea Suspension Bridge is a valuable means of communication for residents in the adjoining localities, and though it cannot be said to take any part in the great metropolitan traffic as yet, still, as building increases, free access to Battersea Park becomes more and more desirable.

Mr. Carr next proceeded to consider the bridges of London as mechanical structures, with reference solely to strength and stability. Beginning with the foundations, he said that the original timber bridges built by the Saxons and Normans across the Thames at London seemed to furnish examples of the importance of driving the piles of such bridges deeper than was then accomplished, for they were easily washed up by floods. The defect of these piles probably led the builders of the first stone bridge into the opposite extreme —viz., making the piles too massive, and by their very mass leading to destruction by increased scour. The piles of the first wooden bridges were not stable; the foundations of old London Bridge were not altogether successful; therefore in building the next bridge (Westminster) another plan was tried, the French system of caissons; in fact, barges in which the piers were partly built while floating, then sunk in place and the sides removed, the site being dredged to receive them. The objections to this plan, are that a perfectly level bed cannot be obtained, and the caisson bottom must inevitably rest in the first instance on limited portions. Increased weight and time will no doubt produce a more even bearing, but it must involve settlement to some extent. The caisson system was adopted at the next bridge built, Blackfriars; the caissons bottoms or platforms on which the piers stood, lately taken up, were 88 ft. by 37 ft., and 2½ balles thick, area 3,256 ft., bearing a weight of 11,241 tons, or 3½ tons per foot super, supposing the whole area to take its share of load equally; but in fact the weight was carried by a much more limited area. The load per foot on the surface of timber area of footing was about 6 tons. Had this weight been evenly distributed over the whole bearing surface, the surface being the London clay or gravel, resting on the clay, the foundation might have been good enough as long as not undermined; but there were symptoms of the arches having yielded on the centres being struck, which leads to the suspicion that the pier foundations had slightly moved, in fact, had come to their bearing as the increased weight came on. In arches Nos. 5, 6, and 7 from the south, lead was found run into joints on the north side, in each case the arches evidently having lurched over to the south, opening the joints on the north haunch. Lead was run in as much as an inch thick at extrados, tapering inwards, the masonry joint being tight at intrados. The opened joints were not in one course through, but stepped a course up or down. It is supposed that some 4 or 5 tons of lead were taken out, but the greater part was stolen. This system of caissons is now universally admitted to be defective and inefficient, principally from liability to be undermined by increased scour. Waterloo Bridge was the first of the bridges built in what may be called the present day—built after the date when engineering had become a distinct profession. The foundations of this bridge were of a totally different character from all preceding; no pains or expense were spared, and everything was done which at the time was considered most efficient. Coffer-dams of double piling and puddle were formed, which did their work most successfully, the foundation being laid dry. Southwark Bridge followed on the same principle, and new London Bridge immediately after. Taking the case of London Bridge, the area of the pier foundations was laid dry, with coffer-dams, 43 ft. below Trinity high water; bearing piles of whole balk were then

driven over the whole space 4 ft. and 3 ft. 6 in. apart, cross sills were laid on the pile heads, the intervening spaces were filled in with rubble and brickwork, the whole planked over, and the piers built on the foundation thus prepared. The weight on the foundation of central pier is about 21,151 tons; supposing this to be evenly distributed over the whole of the bearing piles, there would be a weight of about 88 tons on each pile, and of course, on each sill crossing each pilehead. The specification describes these sills as either elm or fir. In new Westminster Bridge another plan of foundation was adopted, resembling that in building old London Bridge, the object in view being to avoid the expense of coffer-dams. The principal bearing is on 145 elm piles in each pier driven 3 ft. 3 in. and 2. ft. 6 in. centre to centre, and cut off below low water. These elm piles are surrounded with 44 iron piles, 5 ft. from centre to centre, with cast-iron plates driven between the piles, thus forming a complete casing which surrounds and includes the elm bearing piles; the interstices are filled in with concrete, making the whole solid. The weight on these piers is so slight when compared with that on the piers of London Bridge that the question of foundation becomes of less moment. The weight per pile is about 15 tons, supposing the elm piles to carry the whole weight, or about 11½ tons, supposing the iron piles to take their share. Query, would not solid cement concrete resting on a well-prepared bed have made a more efficient and more durable foundation than piles of timber, the insterstices only filled in with concrete? Homogeneity is the essence of strength; one homogeneous mass is the true foundation wherever it can be obtained. The next system of foundation introduced was that of iron cylinders open at the bottom and sunk into the bed of the river by excavating inside first by divers; afterwards, when water-tight strata are reached, by pumping out and working dry, the interior, when a sufficient depth has been reached, being filled solid with concrete or brickwork. The railway bridges at Charing-cross, Blackfriars, and Cannon street are thus carried. Nothing can exceed the facility of putting down such cylinder foundations, and nothing can be better where sufficient area is given, and where such form is suitable to the superstructure. The weight required to sink these cylinders seems to be about 3 tons per ft. of circumference, that weight including the cylinder itself and the load placed on it for driving it down. There is one very important distinction between railway and road bridges. In railway bridges the weight is always carried in the same position, and is naturally transferred on to definite and distinct points; circular cylinders placed under these terminal points of the arch or girder become, therefore, suitable foundations. But the case of a road bridge is different, inasmuch as the varying traffic is distributed indiscriminately all over; the weight and strength of the bridge have, therefore, to be distributed also over the whole width, and consequently a continuous pier is more suitable than such isolated columns as are sufficient for railway bridges.

Having given various interesting details of the rebuilding of Blackfriars Bridge, Mr. Carr said that in the upper portion of the piers of bridges there is not such scope for variety as in the construction of foundations. For the Thames, the right material, no doubt, is granite, and the best hearting is good sound brickwork. Good sound brickwork carefully built in Portland cement or lias lime is stronger work and more solid than even ashlar throughout; but the granite facing must be well bonded in, not such work as is sometimes done—a face carried up of stone nearly of the same depth throughout. The arches of all bridges of any size or importance, up to a late date, were always of masonry; but after various examples of iron had succeeded elsewhere, cast iron was used for the arches of Southwark Bridge. In later times the manufacture of wrought iron has advanced so rapidly, and wrought iron offers such advantages over cast, that it is now almost universally used. The cast-iron arches of Southwark Bridge certainly are a bold and noble construction. It is a singular and almost unique fact with regard to cast-iron arches, that they were in the first instance made much slighter than in later works. The bridge at Sunderland, of 236 ft. span, has arches of about 46 in. area of metal. Southwark Bridge centre arch of 240 ft. span has arches of 6 ft. depth, and 122 in. area. The tendency in all other works

has been to give greater mass in the first instance, and to build slighter in later times. The builders, however, of Sunderland Bridge gave their successors no opportunity of paring down; the margin of stability there was small indeed. The danger with cast iron in general, and cast-iron arches in particular, is that of getting an unequal bearing either from defective fitting, or from expansion and contraction. The rise and fall of Southwark Bridge arches is about 1 in. for ordinary change of temperature, or about 1-40th in. for each degree, such rise and fall must produce considerable variation in the load to be sustained by the extrados and intrados of the arches. The brittleness of cast iron, together with the improved facilities for the manufacture of wrought iron, have led to the almost univeral adoption of wrought iron for arches. If one portion of a wrought-iron arch, say the intrados, should from bad workmanship or other cause have more load to carry than the strength of the metal will bear, a general compression would take place in that portion, and a corresponding shortening, allowing the remainder of the arch (the extrados) to come into play before any mischief took place. Though cast iron in the dimensions usually experimented upon has probably double the power of resisting compression that wrought iron has, nevertheless it is usual not to trust to it with much more than about half the load, showing how strong is the general feeling of distrust in that brittle material. As regards oxidation, however, the balance is much in favor of cast iron, both from a less tendency to rust, and also from the same absolute amount of loss being a less percentage on the greater mass. This is a strong reason against using thin wrought plates in any construction exposed to the weather—the loss, say, of $\frac{1}{8}$ in., by oxidation, would be immaterial in a thick casting, but would be fatal in a $\frac{1}{4}$ in. wrought plate. With regard to Blackfriars Bridge, the ordinary course of heating the iron work and dipping in boiled oil was pursued, four coats of paint following. Asphalt paint for the interior surfaces, and Torbay oxide of iron paint, finished with Messrs. Rose & Co.'s olive green, for the exposed face. The great desideratum of the day, no doubt, is some means of permanently protecting iron from rust; this is now said to be done by Messrs. Turner & Allen, of Upper Thames street; their process is to coat the iron with bronze or copper in such a manner as to effect perfect union between the two metals; if this union of the two metals really be as perfect as stated, no doubt it will prove a most valuable discovery. Having given various interesting details of the strength of materials used in the new Blackfriars Bridge, and described the temporary wooden bridge at Blackfriars, Mr. Carr, in conclusion, treated of the bridges of London, considered as works of art.

EXPERIMENTAL TRIP OF THE INDIAN GOVERNMENT STEAM TRAIN ENGINE RAVEE FROM IPSWICH TO EDINBURGH.

By A. CROMPTON.

From "The Engineer."

One of the stipulations in the contract between Mr. Thomson and the Indian Government, when the former tendered for the supply of 4 high-speed road steamers, was that 1 engine at least should, as a test, travel a distance of several hundred miles, drawing behind it a load. The object of this was to learn as much as possible of their behavior when put to severe continuous work.

With this view the first completed engine, the Chenab, was sent by road from Ipswich to Wolverhampton. The results of this trial, though satisfactory as far as the engines proper, and the india-rubber tires, were concerned, were vitiated by the failure of the boiler, which could not be kept steam-tight, and otherwise gave endless trouble. On the completion of the second engine, the Ravee, the field boiler of which gave excellent results when put through a series of trials with wood fuel on Ipswich Race course, Mr. Thomson, before giving his final consent to the adoption of the same boiler in the remaining 3 engines, desired me to put it

through as exhaustive a trial as that undergone by the Chenab, in order that we might find out the weak points, if any, of the Field system, and furthermore note the effect of continuous high speed on the engines and rubber tires, this high speed having been unattainable with the defective boiler of the Chenab. As the Indian Government had been very urgent for the speedy dispatch of the engines, no time could be wasted in further preliminary trials. The engine and omnibus were ordered to be packed and ready for an early start on the morning of September 13th. In order to save repetition I will give a brief description of the Ravee. She weighs when loaded with 1 ton of coal and 375 gallons of water in the tank about 14 tons ; driving wheels 6 ft. diameter, cylinders 8 in. diameter, 10 in. stroke, geared, fast speed $3\frac{3}{4}$—1 ; slow speed, 12—1 ; revolutions of crank shaft at 10 miles an hour, 157 ; boiler has 50 sq. ft. of heating surface in the fire-box, and 127 sq. ft. in the Field tubes ; grate surface, 11.25 sq. ft. As this large grate surface is especially intended for burning wood, we contracted it to 7.6 sq. ft. by building a ring of fire-brick round the grate. The boiler contains 13 cwt. of water. The omnibus when loaded with tools, luggage, etc., varied from 5 to 6 tons accordingly as coals and the engine shoes were carried in it or not. The gross load, therefore, averaged during the whole journey from Ipswich to Edinburgh a little over 19 tons. Our staff consisted of one fitter, one driver who was a lad of seventeen, one fireman, and myself.

We left Messrs. Ransomes, Sims, and Head's yard in Ipswich at 3.40 A.M. on Friday, September 15th. The road being good and sound, we rattled along at a good pace, and reached Stowmarket at 5. 30, and filled up with water—or rather didn't—as the town pump would only supply us with 250 gallons. This necessitated a stop for water at Woolpit, 8 miles further on. We reached Bury St. Edmunds at 8.15, having run the first 26 miles in $4\frac{1}{2}$ hours including all stoppages for pumping, etc. After getting photographed, having coaled and breakfasted, we started at 10.30. The road was loose and heavy all the way to Newmarket, and the water was very difficult to get. We arrived at Newmarket at 1.27, and found that the waterworks people could not give us a single pailful, as they had not enough to water the streets. The landlord of the Golden Lion, however, came forward, and offered to us in our need the contents of the cistern in his back yard. As the entrance to this yard was too low and narrow to admit the engine, we were obliged to stand out in the main street, and carry the water in buckets, as our hose was not long enough to pump it in direct. Carrying water in buckets is not an intellectual pursuit, and nothing could induce the tight-trousered race-course-haunting inhabitants to lend us a hand, so we had to do it ourselves, and were consequently not in the best of humors when the chief policeman came and told us to "move on." It was too much. I mildly replied, "Mr. Policeman, under the circumstances 'moving on' is impossible ; but if you will kindly 'run us in' to that much desired back yard, I will forward a good report of your engineering capabilities to the bench of magistrates."

We left Newmarket at 2.40, and arrived at Ely at 6.15. The whole of this road was so heavy that the engine was literally ploughing along in 3 in. or 4 in. of loose dust and flints. We had a very narrow and steep iron bridge to cross as we entered Ely ; it barely admitted the engine, 8 ft. 6 in. over all, between its parapet walls. We coaled at Ely, and got a guide for Peterborough—such a designing ruffian! his sole mission appeared to be to guide us into scrapes. Our troubles commenced about 10 miles after leaving Ely. Our guide piloted us into a *cul de sac*, terminating in a triangular piece of ground, as boggy and treacherous as you please. As its greatest diameter was about 30 ft., it required some manœuvring to twist the train round and come out again. A few miles further on we crossed a very indifferent wooden bridge. The wooden bridges in the Fens are most of them built on this plan :—The piers are of piles, and the roadway is laid on 14 in. square oak balks, untrussed in any way. Where the spans are short, this is all very well, but when they get to 18 ft. and 20 ft., as is the case with some of the bridges near Peterborough, traction engines had better go round. However, Meeple Bridge was judged to be safe. Shortly after crossing it, and a second one over the Forty Foot river, our guide insisted upon

our turning sharp round to the left, and taking the road along the top of the bank of the Forty Foot. This road was tolerably wide at first, but gradually narrowed until it was only about 10 ft. at the top, with a steep slope on one side to the river, on the other to the Fen ditch. The surface consisted of a thin coating of metal laid on the springy Fen soil of the bank, and the whole rose and fell under the engine like the waves of the sea. It was an anxious time for the steersman, as he had only a margin of a few inches outside each driving wheel, and if he came within this margin ever so little the side of the bank immediately began to cut and slide away under the wheel. We had 10 miles of this fearful road, but to the honor of the rubber tire, be it said, it never once failed us in a situation where a slip or failure to bite for one single instant would have been a very serious matter. To add to our other troubles, we found that the water of the Forty Foot river was brackish, being admitted from the sea to flush the siphons. Our boiler did not like this at all, and threw it out almost as fast as we put it in. Within a mile of the end of this piece of road a Field tube burst. It acted like a fusible plug and put the fire out immediately. We lay down in the 'bus for a few hours' rest, in order to give the boiler time to get cool. This was about 2 A.M. We had run 69 miles from Ipswich ; 12 hours 9 min. travelling, 11 hours 51 min. for halts and meals ; speed, 5.67 miles an hour ; consumption of water 21.7 lbs. per ton per mile; consumption of coal, 5.6 lbs.; number of lbs. of water evaporated by 1 lb. of coal, 3.85. This day's performance stands alone, as will be seen hereafter, in the enormous quantity of water used, the heavy consumption of fuel, and the low evaporation The first might have been expected on account of the continuous heavy road the whole way from Bury St. Edmunds, and the priming during the last 12 miles, caused by the sea water; but the two last are still a mystery to me. It must be recollected that we had never burnt any coal in the boiler before this day's trip, and were consequently in the dark as to proportion of fire-grate surface and blast required. The engine has still her wood burning fire-bars, and a great deal of fuel is wasted by dropping through them. However, this will not account for the great difference between this performance and that of the ensuing days.

After resting we replaced the burst tube and got up steam. This took about 3 hours. The tube had opened for about an inch near the end, apparently in consequence of defective welding. We started at 12.30, and arriving at Ramsey we were told that the bridge at Whittlesea bore a very doubtful character. After some delay we found out that if we avoided Peterborough altogether we could get on to the great North-road at Sawtry without making any very considerable detour. After 12 miles of cross country lanes we reached the much desired road, and found such a change in the rolling resistance! The engine appeared to leap forward directly we got on to its hard level surface. Here we took off the shoes and stowed them away in the 'bus, otherwise, redistributing the weights, making the engine weigh about 13 tons 10 cwt., and the 'bus 6 tons 12 cwt. Along the great North-road we made capital way, running the 17 miles between Sawtry and Wansford-in-England under 2 hours. Arrived at Wansford we were most hospitably received by Mr. Jackson of Stebbington House, who insisted upon our putting up the engine in his grounds and entertaining us over the Sunday. The result of this second day's run showed an improvement on the first, particularly in the evaporation, which rose to 4.96 lbs. of water per lb. of coal. The average speed was 6.8 miles; consumption of water, 16.1 lbs. per ton per mile; consumption of coal, 3.25 lbs. per ton per mile.

On Monday morning we started at 6 A.M., reached Stamford, 6 miles, in 35 min.; Grantham, 26 miles, at 11.15 A. M. After breakfasting and watering, we ran to Newark, 15 miles, in 1 hour 40 min. We ran most of the way at the rate of a mile in 4 to 6 min., according as the ground was level or undulating. We should easily have averaged 12 miles an hour, but for the frequent stoppages for horses, the slow speed through villages, etc. We arrived at Retford, 6.55; Bawtry, 10.45; Doncaster, 11.30; and laid up the engine for the night in the Wool Market. We had run 83½ miles in 10 hours 25 min. of travelling, 7 hours 31 min. for meals and pumping water—speed 8 miles an hour. The only noticeable thing to-day was the ease with which the engines

worked, the small horse-power required, and consequent economy of fuel—much of this last due, no doubt, to the excellence of the road.

A serious defect showed itself in the rubber tire of the steering wheel during this day's run, which afterwards necessitated its removal. On submitting this tire to the examination of the rubber manufacturers, the only cause which could be assigned for its failure was imperfect, or rather insufficient vulcanization.

The following morning we left Doncaster at 9.7 A. M., and arrived at Boroughbridge, 42 miles, at 7.55 P. M. At this place the defective tire was removed, and wooden felloes, hooped with iron tires, substituted. This made the steering wheel a rigid one, and its use an interesting experiment. But a few miles showed that, although the steering-fork is carried on steel springs, nothing over the speed of 5 miles an hour could be attempted without fearful jolting and fracture of the steersman's teeth. The remainder of the journey to Azerley Hall, near Ripon, was accomplished in a couple of hours; the result of the run from Doncaster being as follows :—Speed, 5.6 per hour; consumption of water 16.28 lbs. per ton per mile ; consumption of coal, 3.00 lbs. per ton per mile; pounds of water evaporated by pound of coal, 5.37. Part of the road between Doncaster and Tadcaster was very hilly, the last few miles to Azerley Hall a mere country lane. At Azerley we had to wait two or three days for the spare tire, and when we had got it were detained weather-bound for several days longer. Your readers will recollect the exceptionally heavy rainfall of the last week in September. Seeing no chance of the weather clearing, we put on the shoes, and started from Azerley at 8 o'clock on Monday morning, the 2d of October. We found the road so much better at Ripon that we removed the shoes again, and made a rapid and economical run to Darlington, 40 miles from Azerley. Although the road was wet and slippery, it was free from greasy mud, and we were able to get along without the shoes. The results of the run this day, without shoes, were as follows:—Speed, 8.5 miles an hour; consumption of water, 13.1 lbs. per ton per mile ; consumption of fuel, 2.36 lbs. per ton per mile ; evaporation, 5.70 lbs. This is about the best performance made by the Ravee when burning coal. We left Darlington the following morning at 8.45. Just after passing Ferryhill, at 12.35, we found that one of the connecting rods was bent; we took it out and straightened it; this occupied 7 hours. We got under way again, and arrived at Durham at 9 P. M. We found some of the paved streets of Durham presented the steepest gradients of any we had hitherto met with, and felicitated ourselves on having put on the shoes at Darlington. Arrived at High Level Bridge End, Newcastle, at 3.10, and were refused leave to go over. The man in charge said nothing over 7 tons had been allowed, so we had to turn round about and go down to the Low Level Bridge, and then up the steep and greasy gradients of Dean street, which we ascended at the speed of 6 miles an hour, although I should think the gradient is 1—13. Coaled at Seaton Bourne Colliery, at the very pit mouth, and reached Morpeth at 10.40. After breakfasting, and coaling, we set out across the bleak moorland road to Wooler, and not often before, I suppose, was such a road traversed by a traction engine. The road is one series of ascending and descending inclines, most of them long and steep. Outside Wooler we had an amusing passage of arms with the toll-gate man, who deliberately refused to open his gate. The head lamp was removed, and the flange of the framing of the engine placed gently against the gate; it was wonderful to see how easily the gate opened, without a murmur, I should say —and the tollman's face! At Wooler, at 11.45, we were refused admittance at the miserable little inn, because we were so dirty that the landlady was "sure we should dirty the sheets so much that the commercial gentlemen would not like to use them after us." The men got shelter somehow, and I improvised a shake-down out of the 'bus cushions. The coal, although only 3 or 4 miles from the pit mouth, is here sold in bowls, holding about 100 lbs. each, at something over 1s. a bowl. If the gentleman in "Punch" in search of quiet were to go to Wooler I think he would find it.

The results of this run of 78 miles were, speed 4.05 miles an hour. This was on account of the constant gradients, the frequent stoppages for horses near Durham and Morpeth, and the continuous

rain. Almost all the streams were in flood, and the water taken very muddy. Consumption of water, 17.9 lbs. per ton per mile; consumption of fuel per ton per mile, 3.70; evaporation 5.01. We were 19 hours 15 min. travelling, and 20 hours 15 min. halting. The following morning, October 5th, we started at 8.30 A.M., and arrived at Cornhill Railway station, near Coldstream, at 10.50. Here, whilst standing to take in coal, occurred almost the only accident from horses that happened during the whole trip. A string of carts laden with lime was passing the engine, which was drawn to one side of the road; two or three of the horses got frightened, and capsized their carts against a wall; luckily, no one was hurt, nor were the carts broken. The hinds were very sulky at having to shovel all the lime into the carts again. Passed through Kelso at 3.55, and had a considerable bother under the Duke of Roxburghe's wall at Floor's Castle. The Duke's wall is high, and does not allow the wind to dry the road; consequently, all along under the wall there is a coating of green, slimy soil, which is not favorable for traction engines. As we, poor innocents, were journeying along in this stuff, we had to draw up and wait some little time to allow some carriages returning from the races to pass. On starting again we found we had settled into a mess of butter, and it was only by scheming and scraping the road, and using Mr. Aveling's device of always backing out of a difficulty, that we got out. On the top of the hills before reaching Earlston, we had to shorten the shoes, and it was a bitter cold job. I never knew wind to blow so sharply. We halted for a time at Lauder, and made a good run up Lootray Hill, an incline of some 3½ miles in length, and varying from 1 in 25 to 1 in 17, gaining both steam and water as we ascended it. Got breakfast at Blackshields, watered at Dalkeith, entered Edinburgh by the Dalkeith road and the bridges, ran along Princes street to the west end, and laid up the engine and 'bus in Messrs. Drew and Burnett's yard, Fountain Bridge. A couple of days afterwards we took the train out for a trip, for the inspection of Mr. Monteath, the Director General of the Indian Post-office; and on the following Monday, to satisfy that gentleman as to the engine's power of hauling heavy loads up steep inclines, we took her out, with a load of wagons full of lime, to Mr. Bruce's farm, some 27 miles from Edinburgh. In the course of this experiment the engine drew 4 wagons loaded with lime up an incline of 1 in 17, more than a mile in length, being the ascent of the Lammermuir Ridge on the Edinburgh side. As the wagons, with their load, weighed 26 tons 10 cwt., the gross load was over 40 tons, which gives 64 horse power as the dynamometrical horse power. I will, with your permission, give the performances of the engine in a future number in a tabular form.

STEEL MANUFACTURE IN BIRMINGHAM.

From "The Mechanics' Magazine."

The "Premier Steel Works," of Messrs. Cox, Brothers, and Holland, occupy extensive areas in three different parts of the town of Birmingham, namely, Alcester street, River street, and Glover street.

These works, as the name implies, were the first, and are indeed the only, manufactory of steel in Birmingham, and their origin possesses so much intrinsic interest, and is so typical of the great and rapid development of the town generally, that some account of them will be found instructive.

This firm has long been engaged in the production of steel frames for umbrellas, sun-shades, etc., which require steel of peculiar temper and elasticity, uniformity of quality being essential. While their trade was confined within moderate limits, there was but little difficulty in obtaining material of the particular quality required, but as their transactions increased, the demand exceeded the supply. The difficulty grew in almost the exact ratio of the extension of their business; and thus in time became a matter of serious importance, necessitating special arrangements. After many experiments and efforts in various directions, it was finally determined to enter upon the manufacture of the article for themselves, and the result has

borne remarkable testimony to the wisdom of this course, for they now not only provide for the large requirements of their own business, but produce steel of every description, which is sent in great quantities to all parts of this country, and exported extensively to every quarter of the globe.

We propose, in this notice, to confine our attention to the system of steel manufacture as practised in these works, reserving for a future occasion an account of the construction of the umbrella frame, which has to pass through 100 pairs of hands and is the result of remarkably delicate and ingenious manipulations; but some idea of the extent of this manufacture may be gathered from the fact that the weekly production falls little short of 50,000 sets of frames.

The composition of steel is still surrounded with mystery, but as we so lately published a paper upon the subject, its consideration here is not necessary.

The iron used for conversion into steel is of Swedish origin, and is received in bars 3 in. wide, $\frac{5}{8}$ths of an in. thick, and about 12 ft. long. These, after being straightened so as to lie evenly, are placed in the converting furnace, which consists of two rectangular vessels, technically called "a pair of pots," made of silicious freestone, capable of enduring great heat without change; in dimensions 12 to 14 ft. long, 3 ft. 6 in. wide, and the same in depth. They are supported upon a depth of 4 ft. of solid masonry, the top course being of firebrick, to prevent settlement, which would crack the pots, admit air, and spoil the conversion. Upon this masonry are constructed transverse or sleeper walls of firebrick, 10 in. thick, and 10 in. apart, upon which the pots rest, the brick divisions forming flues underneath. The pots are placed parallel to each other, but 18 in. apart; the space between them is divided into flues, corresponding with those underneath, extending up the sides and ends of the pots into the firebrick wall which covers the whole. This vault has an arched opening, or manhole, at each end, for charging the pots with iron, or taking out the charge when converted into steel. During conversion they are bricked up and plastered with clay. There is also a small opening over each pot, through which bars can be put. Out of the vault rise 3 chimneys on each side, opening into a large cupola. The fire-grate is under the middle flues and the whole length of the pots, with a strong metal door at each end, kept closely shut, except when being charged. Each pot has a stratum of charcoal evenly laid on the bottom, above which a layer of bars is placed, and covered $\frac{1}{2}$ in. deep with charcoal; bars and charcoal are thus laid alternately until the pot is nearly full, and finished off with a thicker covering of charcoal over the top. The pots, when filled, are covered over with 5 in. of "wheel swarf," which contains iron and steel in minute particles, and, becoming partially fused when hot, perfectly protects the steel underneath from the action of the air. Each furnace has a 5-in. opening through the walls and into the centre of one end of the pots, through which 2 or 3 of the top bars project, the opening being filled up with fine ashes, well rammed, to exclude the air. The fire, gradually raised to great intensity, is kept up for 6 or 8 days. A furnace holds about 16 tons of iron, and is considered to be well worked, if 14 to 16 heats are got out in a year.

When the conversion is supposed to be nearly complete, a top bar is drawn, and, when cold, is broken; its condition shows the state of the whole, and the fire is regulated accordingly. A second or third bar is subsequently drawn, and when the conversion is considered to be complete, the fire is allowed to go out. In 4 days the man-holes are opened to hasten the cooling, and in 4 more the steel, still hot, can be taken out. A full furnace charge is called "a heat of steel," and according to the degree of carbonization required, is called "a spring heat," "a cutler's heat," "a shear heat," "a file heat," or "a melting heat." It should be premised that these terms do not apply to the "temper" of the steel, but to the length of time in furnace.

The bars are now broken and sorted by experienced workmen into the various tempers; the hardest are laid aside for melting, and the softer hammered into shear or spring steel. Those required for shear-steel are broken into lengths of about 1 ft.; are next laid upon each other, 3 or 4 together; then heated in a furnace, to "welding heat," and drawn under the hammer to the size intended. It is then "single shear" steel. If again broken, heated, and hammered, it becomes "double shear" steel, an extra quality used for

best table cutlery, and other first-class purposes. Spring steel is made from bars passed at a red heat between grooved rollers until reduced to the particular size required. Shear and spring steel are the chief, if not the only qualities manufactured direct from the converting furnace.

We now come to the important process of cast steel.

The invention of cast steel is assigned to Benjamin Huntsman, who perfected it in 1740, after many experiments, and repeated losses and discouragements. He carefully guarded his secret, and for a long time with success, till it was discovered, as it is said, by a rival manufacturer disguised as a beggar, after which the manufacture soon became general. The melting process is as follows: The steel is broken into small pieces, and put by means of a conical-shaped funnel into a melting pot or crucible holding about 34 lbs., made of a peculiar dark gray clay. Before charging the crucibles they are gently heated to a red heat on an annealing grate, and then placed with covers of the same material upon fireclay stands in the melting furnace, and covered with coke, till furnace and pots are at a white heat. Each furnace holds 24 crucibles. These are kept covered by fresh supplies of coke as required, till the metal is thoroughly melted, which is known by its clear surface and motionless state in the pot. When ready, the crucible is taken by tongs from the furnace, and the steel is poured slowly into moulds prepared for its reception. The moulds can be opened, and the ingots taken out, and removed into the yard to cool, a few minutes after they have been cast. As soon as the pots are empty, the lids are put on and then are replaced in the furnace, a quantity of coke is put in, and the holes are covered. When the coke has burned down so as not to be higher than the pot lids, a fresh charge of steel is put in and the former process is repeated for a second and a third time, after which new pots are necessary.

Heath's process of melting is also adopted to a considerable extent in the works. This consists in cutting the bars into pieces, placing them in the pots with a certain amount of charcoal, and when brought to a melting heat, sufficient manganese is added to make the steel weldable. Steel thus prepared is particularly adapted for all purposes where soft welding is required. In some instances spigeleisen is also added as a ready vehicle for imparting the manganese.

Tool steel, sheet steel, and steel wire are the chief classes into which cast steel is manufactured.

For tool steel the best ingots are selected. The ends of each being broken to determine its texture and temper, it is heated to a red heat, and drawn under the steam hammer to the sizes required,

For steel wire the ingots are roughly drawn under the hammer into billets, $1\frac{1}{4}$ in. square, and sent to the rolling mill, where they are passed at a red heat between grooved rollers, and reduced at one heating to a $\frac{1}{4}$ of an in. thick, and from 2 ft. run out to 70 ft. long. The rapidity of the rolls is such that, notwithstanding the partial cooling of the steel by lying on the floor, during its passage through the rolls it becomes re-heated from "warm red" to "bright red" by their action. From the last pair of rolls the rods (as they are now called) are coiled upon a drum about 26 in. in diameter, tied in bundles, and passed to the wire mill, where they are subjected to an annealing process, and an acid bath, and are then drawn through steel plates while cold. These operations are repeated from 3 to 5 times, according to the fineness of the wire required. The wire used for the umbrella frame ranges from 13 to 15 wire-gauge numbers. For other purposes any degree of fineness can be obtained.

The process of annealing is as follows. The wire is placed, coiled, in large quantities in a cast iron vessel, actual contact with which is prevented by the insertion of bricks into cast iron ribs. The vessel is closed, and very gradually brought with its contents to a red heat, at which it remains from 12 to 15 hours, when it is as gradually cooled.

To produce sheet steel, large quantities of which are demanded for the steel-pen trade, the ingot is treated as before, but hammered to about $\frac{5}{8}$ths of an in. thick. It is then taken to the rolling mill and passed through flat rollers while at red heat, till it is about 22 wire-gauge. In this state it is suitable for circular saws, and kindred purposes. It is next subjected to the annealing process and acid bath, and then rolled in a cold state till it becomes hard, or, as it is technically called, "dense." The first annealing will permit

the steel to be reduced to 30 wire-gauge. The annealing and bathing processes are repeated as often as the steel requires softening and cleaning, till the desired sizes are obtained. This cold-rolled steel is turned to a variety of uses, such as clock and watch springs, children's toys, etc.

Steel has been rolled at these works to a substance but little, if any, thicker than the leaves of this magazine.

NOTES FROM GERMANY.

From "Engineering."

THE HODGSON WIRE TRAMWAYS.

An Hungarian engineer, Mr. T. Bush, has made some improvements on the Hodgson system of wire tramways by employing two parallel cables instead of one. The modified system, it is said, possesses great advantages over the original one, especially with regard to the carrying of heavy loads, and the greater security of the ropes.

METAL FOR BEARINGS.

The following alloy has been found to give highly satisfactory results for plummer blocks, axles, brasses, etc. To 30 parts of melted copper are added 70 parts of antimony; the mixture is melted and run out into thin plates. These are then remelted with tin in the proportion of 90 parts of tin to 10 parts of the copper and antimony, and run out again into thin plates. When used it is remelted, and run into the form required. M. Volk, of Regensburgh, has employed an alloy for many years, of which the following are the component parts: Copper, 5.6 per cent.; antimony, 11.2 per cent.; and tin, 83.2 per cent. He also employs the following mixtures to produce metals for various purposes.

For slide valves:		
Copper	81.9	per cent.
Tin	14.8	"
Zinc	3.3	"
	100.0	
or		
Copper	67.0	"
Old brass tubes	32.0	"
Tin	10.2	"
For pump barrels, stop-cocks, and valve-boxes:		
Copper	87.7	per cent.
Zinc	10.7	"
Tin	1.6	"
For stuffing-boxes, valves, etc.:		
Copper	86 2	"
Zinc	3.6	"
Tin	10.3	"
For eccentric rings:		
Copper	90	"
Zinc	10	"
For piston rings:		
Brass cuttings	94	per cent.
Copper cuttings	6	"

COAST PROTECTION BY TORPEDOES.

Contact and electric torpedoes were both employed for the protection of the German coast during the war. The former had generally a charge of 82 lbs. of powder, and were moored about 3 ft. below the surface of the water. The electric torpedoes were loaded with 220 lbs. of dualin, equivalent to 1,100 lbs. of powder, and were fastened 8 ft. below the water. The explosion of these was brought about by means of batteries placed on the shore, and they were perfectly safe. On the other hand the contact torpedoes were exceedingly dangerous to handle, and three fatal accidents took place in lifting them from their positions. In addition to the defence torpedo, attempts were made to project others beneath the hulls of the hostile vessels, but nothing resulted from this application.

DYNAMITE IN WELL SINKING.

In Denmark dynamite has recently found a novel application, namely, in the sinking of artesian wells. During the autumn of last year, some persons sinking a well at Gjeddesdal struck upon a very hard bed at a depth of 75 ft., which they were quite unable to pierce. As there appeared no choice but to abandon the work, they ultimately determined to try the experiment of a charge of dynamite.

After the bore-hole had been cleared, a bottle containing about 2.2 lbs. of dynamite was lowered. It was attached to two copper wires passed through the stopper of the bottle and insulated by gutta-percha. When the charge was in position, an electric spark brought about the explosion, with the result of a great concussion on the surface, and an upward discharge of the water which stood in the boring.

The hole almost immediately filled with water; giving evidence that the obstruction had been removed, and the source of supply reached.

Two charges were afterwards fired in a similar manner and the sudden rush of water left no doubt about the successful issue of the experiment.

ASBESTOS PISTON-ROD PACKING.

From "The Engineer."

Few engineers who have to do with the steam engine are ignorant of the trouble which is met with in obtaining a really good piston-rod packing. Sound hemp properly "laid up," and copiously lubricated, makes a tight joint enough for a time, especially if the rod is in first rate condition; but the period of tightness is usually short, and the gland requires constant screwing up, and much friction results which is very prejudicial in small engines. If hemp is bad in the case of low-pressure engines, it is infinitely worse when we have to do with high steam, especially if the steam is slightly superheated. A process of slow carbonization appears to go on, the hemp packing loses its elasticity, and becomes nearly useless for its intended purpose. All manner of schemes have been tried to get over the difficulty, combinations of cotton, india-rubber, and wire gauze, such, for example, as Crickmer's patent packing, have hitherto given on the whole the best results. One inventor, indeed, dispenses altogether with cotton and rubber, and uses copper wire gauze alone. In this case the tightness of the joint is no doubt secured by the presence of water and oil lodged in the meshes of the gauze; and we have received very favorable reports from those who have tried this packing. It is still certain that something better than anything hitherto in use is required, and we have a strong belief that this something is supplied by asbestos.

Asbestos is a mineral fibre consisting of silicate of magnesia, silicate of lime, and protoxide of iron and manganese. In mineralogical parlance, it is a fibrous variety of actinolite or tremolite. It exists in vast quantities in the United States, also in the Tyrol, Hungary, Corsica, Greenland, Wales, Cornwall, Banffshire, and in the north and east of Ireland. It is found under various forms, from that of soft silky fibres to that of a hard block capable of taking a polish. As a rule, the lumps or blocks taken from the vein are easily broken up and separated into fibres extremely flexible, and elastic in the sense that each fibre admits of great extension in the direction of its length without contracting again, greasy to the touch, and very strong. The fibres vary in length, from a couple of inches to about 2 ft. They can easily be spun or woven, if proper precautions are used. Furthermore, asbestos is an admirable non-conductor of caloric, and it is practically indestructible by heat. All these conditions are just those which are required in a material for piston-rod packing; and it is therefore somewhat strange, that until a very recent period no one thought of utilizing asbestos for this purpose. The credit of suggesting it as a piston-rod packing is due, we believe, to Mr. St. John Vincent Day, C. E., who read a very interesting paper on "Asbestos, with special reference to its use as steam-engine packing," before the Institution of Engineers and Shipbuilders in Scotland. The new packing, we learn from this paper, was first used in America with much success, and it has since been tested in this country with results of which we shall speak in a moment. In referring to the value of the new packing, Mr. Day said: "The packing used for piston and valve rods, or spindles, has, as we all know, three prime elements of destruction to contend with, namely, an elevated temperature, friction, and moisture, and one of them only, namely, friction, has any appreciable effect on asbestos packing when the mineral is pure and properly prepared. No matter how high the temperature of the steam, how rapid the stroke of the piston, or how great the pressure of the steam, the packing seems to be unaffected by those conditions. In America, where the new packing was first used, some of it was taken from the piston-rod stuffing-box of a locomotive engine, after having been in, and the engines at constant work, for 3 months, with steam at 130 lbs. pres-

sure per sq. in., and making an average daily run of 100 miles, including Sundays; and, as you can see by the sample shown, the fibre, with the exception of being discolored by oil and iron, is just as flexible and tenacious as originally. After having been once disintegrated, it appears impossible to so pack or mat the fibres together that they are not easily separable by the fingers."

Asbestos packing was first used in Great Britain by Mr. Benjamin Conner, locomotive superintendent of the Caledonian Railway, and Mr. Day exhibited to the members of the Institution the packing of a locomotive stuffing-box which had been used on that line from the 27th of July, 1871, to the 18th of November. The engine in which it was used has outside cylinders, and single drivers 8 ft. in diameter. The piston stroke is 2 ft. The engine was employed in working the fastest train on the Caledonian line; to wit, the 10 A. M. express from Glasgow, reaching Carlisle at 1 P. M., with three stops on the journey. The best ordinary packing lasts, under these conditions, 2 months at most, rarely so long, and the gland requires constant screwing up. The asbestos packing was apparently as good as when it was put in, and the engine had run a distance of 2,000 miles in 3 weeks, during which the gland screws had never been touched. The following letter from Mr. Conner to Mr. Day contains valuable testimony to the excellence of the packing :—

"The box herewith contains the asbestos packing put into a piston-rod stuffing-box of one of our main line service passenger engines on 27th July, and taken out on 18th November; in that time the engine had run 14,070 miles.

"As the packing was put in coiled instead of being cut into rings, the gland was nearly home on 12th September, and an additional ring was put in at that date." In the course of the discussion Mr. Conner stated that: "The advantage of the asbestos packing over the soapstone packing was, that with the latter, at the high temperatures of steam from 125 lbs. to 130 lbs., the lower portion of the packing got thoroughly charred, and another ring had to be put in after the first week; so that in course of a month the packing had almost entirely changed. The asbestos packing being practically incombustible did not waste; he suggested that the covering of the packing should be made of incombustible material also. At first he had applied it coiled round the piston-rod continuously, but he thought it should be applied in rings. The inside of the packing seemed to him as fresh as when first put in. He believed it took less oil to lubricate the piston-rod, for the oil remained on the rod, not being absorbed by the packing. It kept the rod beautifully polished, more so than with any other packing."

We think that with such testimony as this before us, supported further by that of Mr. David Rowan, who spoke to the value of asbestos packing for marine engines, we are fully justified in holding the belief that this mineral will supply a way out of one of the most troublesome obstacles to the use of very high-pressure steam. There is, furthermore, not the slightest chance of the supply being exhausted; on the contrary, it is likely to last as long as our coal-fields. We are unable to say at present what the price of the asbestos packing is, or where it can be obtained. It is, probable, however, that when once the value of the material as a packing is recognized, its regular manufacture in this country will follow.

UTILIZATION OF COAL DUST.

From "The Philadelphia Ledger."

FRANKLIN INSTITUTE, PHILADELPHIA,
December 19th, 1871.

The Committee on Science and the Arts constituted by the Franklin Institute of the State of Pennsylvania, for the Promotion of the Mechanic Arts, to whom was referred for examination specimens of artificial fuel prepared by Mr. E. F. Loiseau, of Philadelphia, report that they have made trials of the samples produced from anthracite and from bituminous coal.

The mode of manufacture, as related by Mr. Loiseau, is as follows :

1st. Anthracite small coal and dust were mixed with (7) seven per cent. of clay, and compressed into cylindrical moulds

about 4½ in. in diameter and 4 in. deep, or else into spherical masses, about 3 in. in diameter.

2d. The moulded masses are placed for a few minutes, in a bath of benzine in which rosin has been dissolved, and from which they are removed and dried by an exposure to a current of air.

The object of coating them with a film of rosin is to prevent the absorption of moisture and consequent softening of the clay; the solution in benzine penetrates the mass of coal and clay to a depth of about ¼ of an inch and so efficiently closes the crevices that samples immersed in water for 12 hours were found dry in the interior when broken up for examination.

Both the anthracite and bituminous fuels were burned in a furnace measuring 9 in. in diameter and 7 in. in depth; each variety of fuel burned freely and was completely ashed, but the intensity of the combustion was less than that produced by anthracite or bituminous coals of small size burned in the same furnace.

These comparisons were made with a moderate and also with a strong draft.

The average amount of ash obtained from the anthracite artificial fuel was 16 per cent., and from the bituminous artificial fuel was 18.5 per cent.

The heating powers as obtained from trials in Thompson's apparatus are as follows :

One pound of anthracite artificial fuel evaporated	"	4.30 lbs.	of water.
"	"	8.50	"
"	"	7.80	"
"	"	6.76	"
An average of		6.85	"
One pound of bituminous artificial fuel evaporated	"	9 35 lbs.	of water.
"	"	11.11	"
"	"	12.88	"
"	"	10.61	"
An average of		10 90 lbs.	of water.
The anthracite average is		7.40	"

The average of bituminous is 14.88 lbs. of water.

The non-uniformity of result is partly due to the imperfect manipulation in mixing the coal and the clay, and partly to the varying amounts of solution of rosin absorbed in the bath to which the material is subjected. The imperfect manipulation can be remedied by the adoption of proper machinery for that part of the process.

The ability of the artificial fuel to bear transportation is less than that of anthracite, or good lump bituminous coals, but the structure is firmer than that of any bituminous and semi-bituminous coals that are carried to market. The masses will generally break up with a fall of 3 ft., upon a stone pavement, but are strong enough to bear ordinary handling and transportation, and should they become broken would suffer no damage, unless exposed to wet.

The samples of artificial fuel examined are well adapted for use for purposes in which great intensity of combustion is not desired.

For the production of steam in stationary boilers and for household purposes it can be employed equally as well as any ordinary coal; and whenever the cost of preparation is less than the cost of mining coal, this invention will make available the immense amounts of small coal now allowed to remain useless at the coal mines. It appears to work far better than the balls or bricks of coal dust and clay and lime that came into vogue in this city many years ago, when anthracite was brought to market without preparation by the coal breaker, which had not then been invented, the balls or bricks thus made not having the protection from wet secured by Mr. Loiseau by his resinous coating.

We consider the method of preparing artificial fuel from waste anthracite and bituminous coals as presented by Mr. E. F. Loiseau, as ingenious and well adapted to the purpose, and worthy of the attention of those interested in the production of a cheap fuel, adapted to a great variety of uses.

Respectfully submitted. Signed,

CHARLES M. CRESSON,
WILLIAM H. WAHL,
JOHN WISE,
} Sub-Committee.

REMARKS.

1*st*. The percentage of ash is larger than in ordinary coal, as the clay is not consumed; but the other advantages of the coal in point of durability, cleanliness and cheapness, more than compensate this small disadvantage.

2*d*. The samples of artificial fuel presented to the Franklin Institute to experiment upon were simply compressed by hand, and could not be made as solid as

they will be when compressed by appropriate machinery.

3*d*. The cost of manufacture at the mines, including the coal and all the material, will not exceed $1 per ton.

E. F. Loiseau.

CAR PROPULSION BY PNEUMATIC POWER.*

By JAMES A. WHITNEY, Mechanical Engineer.

Long after the success of Stephenson's engines was assured, and the superiority of locomotive traction to that of ropes actuated from stationary engines fully demonstrated, there were not wanting projectors and engineers who sought, at much cost of invention and money, to substitute the now universal mode of railway propulsion by one in which the traveling motor should be dispensed with. Nor were these without plausible argument, nor have their efforts, unfruitful in their time, been unproductive of much that may be of value now and hereafter. The original cost of a locomotive, as compared with that of a stationary motive power, is approximately as 5 to 1; it requires a fireman as well as an engineer, while an ordinary stationary engine is well cared for by a single attendant; it cannot ascend steep grades, and in wear and tear is subject to rapid and often to dangerous deterioration, even with a degree of attention which with most fixed engines and steam-generators is unusual. Add to this that the economy of fuel is much greater with the latter than the former and that fuel of poorer quality may be used, and there is good reason apparent for the numerous plans for transferring the power derived from the steam engine by some other agency than that of direct connection by pitman, crank, and axle. Foremost of the projects has been that of using atmospheric air under pressure, which has been proposed in many different forms. In open country and in direct competition with the locomotive system, it came to grief in every instance. This was not wholly a result of any engineering or mechanical objection—although such were not wanting, for a line between Paris and St. Germain was open to passenger traffic for a period of 14 years—but on the score of expense, which was found excessive.

But it must be remembered that the experiments commonly held to have settled the impracticability of the system were prosecuted under conditions the most favorable to steam locomotion as ordinarily defined. In the exigencies, however, of the present as concerns passenger traffic in large cities, circumstances are wholly changed. On account of noise, of smoke, of the frightening of horses, and of uncomfortably heating the vehicles in summer, steam cannot be used to advantage on city or street cars; neither, for several of the reasons just noted, should its use be attempted in tunnels; neither, on account of the vibrations incident to a locomotive, should such be allowed on elevated ways in which the permanent stability of the supporting structure must largely depend on the absence of disintegrating causes like that just mentioned, and on which the dangers of leaving the track, of collisions and the like, would, under the stress of crowding of city transit, be largely in excess of those experienced on common railways. It is acknowledged that horse-power is already inadequate to the needs of New York city street railways; the transmission of power by wire ropes, as illustrated in the elevated railway on Greenwich street, has proved a mediocre and insufficient method of propulsion; and in pneumatic power alone does there appear to be promise sufficient to justify the outlay required in thoroughly testing any improved system of propulsion. We use the term improved as distinct from the term new, for the plans which offer the most of utility are in their essential principles quite old, some older than the locomotive itself, and the modifications which will render them practicable will, quite likely, be in themselves very slight. But the importance of little things cannot be overestimated in adapting an engineering principle to actual use. It was the adoption of the grooved rail, permitting the flanges of the car-wheels to keep them on the track while the surfaces of the latter lay flush with the street

* Paper read before the New York Society of Practical Engineering, Jan. 3, 1872.

surface so as to offer no impediment to ordinary vehicles, that rendered street railways practicable. Had it been attempted to retain the T-rail, the city tramways, enabling 2 horses to draw 5 times as much as the team of an omnibus on a Broadway pavement, would not, as they have done, gridironed every large city in the country, made their way as an evidence of American enterprise into the capitals of Europe, and trailed their iron length along the streets of Stamboul, as it is stated they are now about to do. A careful working out of the details in the apparatus employed, the adaptation of one or the other variety of pneumatic propelling mechanism to the precise conditions most favorable to its success, and the application of more efficient means in the prosecution of the work than was possible with the inferior workshop practice of 40 years ago, will, we have faith, bring about a practical change in city and suburban locomotion ultimately valuable in every city in the civilized world having more than 50,000 inhabitants. To suggest methods by which, as the writer believes, this may be most readily and effectually brought about, is the object of the present paper.

Propulsion by pneumatic pressure may be properly divided under 3 heads, viz., that embracing the driving of a car or carrier bodily through a tube, either by an air-blast behind it, or by pressure induced in rear by a partial vacuum in front; that in which a piston operated in the same manner as in the former, but in a tube of smaller diameter, is connected to a car running on rails outside; and that in which air under compression is admitted to engines in lieu of steam, the engines being thus actuated to turn the wheels of the vehicle by approximate connections. In the first, a low pressure acting on an area if anything larger than the cross-section of the car is used: its greatest disadvantage is that, as hitherto applied, the car has been projected in darkness through a subterrene tube, reliance being had mainly upon artificial illumination. The second requires a comparatively high pressure, acting upon an area proportionally smaller than the car section, and the cause of its failure after long trial was the leaking of the longitudinal valve, whereby connection was allowed between the piston and the car arranged externally. The third is simply the use of air springs, in which power is stored by compression, to be slowly given out as the air is passed to and through the engine cylinders: among the objections attending its use is the difficulty of maintaining a uniform pressure in the supply to the engine; but of much more practical importance is the liability to freeze, induced in the engine from the heat rendered latent by the expansion of the air. These, the just enumerated principal defects incident to each modification of the pneumatic system, do not seem, in either case, to be beyond the reach of remedy, but in none does the theory or practice of such remedy appear to have been properly wrought out with special reference to the peculiar needs and conditions of city passenger transit.

The several varieties of pneumatic propulsion appear to have grown out, as it were, one from another, in a kind of natural sequence. It is 61 years since James Medhurst, in England, proposed to drive cars by an air-blast through a brick tunnel, furnished with longitudinal ledges to support the rails upon which the car-wheels were to run; it is presumed that the air current was to be produced by an apparatus similar to the blowers used in iron furnaces of that time. Fourteen years later, James Vallance patented a plan in which the air was to be exhausted in front of the car, and from the two it was but a step to combine them in such manner as to secure a maximum of speed. Apparently reflecting upon the evident objections to a tunnel railway, Medhurst, in 1827, 17 years from the date of his first project, planned what is really the germ of the second sub-system. This comprised a tube submerged throughout its length in water, and with an opening longitudinally in its under side, from each edge of which flanges projected downward, so that a water lute of several inches depth was provided to the opening. A piston, propelled by atmospheric pressure, was to traverse within the tube, and, connected by a thin metallic blade or bar with the train upon the external track above, would propel the same. The idea, impracticable in this form, was taken up by Henry Pinkus, who made the longitudinal opening in the upper part of the tube or main, and placed in appropriate rela-

tion thereto a flexible rope to serve as a valve. As the piston—moved by the pressure behind, obtained by the action of air-pumps exhausting in front of the piston—moved forward, it lifted the rope or valve to permit the passage of the colter or connection between the car or cars outside and the piston within. Although the external pressure of the air upon the valve was calculated to keep the latter in place, it was found to leak badly, and the plan amounted to nothing. In 1839, Samuel Clegg patented, in England, a valve adapted to the longitudinal slot of the tube, and remarkable for the ingenious adaptation of its structure to the end proposed. The valve was "made of a double strap of leather or raw-hide riveted between two iron plates, the top plate wider than the slot or opening, and the lower one falling into it when the valve was closed, thus completing the cylindrical form of the interior of the pipe, which had been destroyed by the aperture cut in it." One edge of the leather was allowed to rise, the other being screwed down firmly to the surface of the pipe. The lifting edge lay, when closed, against a composition of beeswax and tallow, placed on the edge adjacent and serving as a solder. The leading carriage of the train carried a trough filled with burning charcoal, and having a blade of copper projecting downward from it. This blade, being kept continually hot, and coming in contact with the valve after the passing of the colter, melted the waxy composition, and cemented the lifting edge of the valve firmly to its seat, thereby hermetically closing the tube to provide for the passage or propulsion of the succeeding train. Samuda combined with this a method of dividing the tube into sections of any desired length, and separated from each other by valves. These valves were actuated each by contact of the leading car on an external lever connecting with the pivotal bearing of the valve. This enabled a vacuum to be maintained separately in each section to propel the train its entire length, without interference with the movement of a train on any adjacent section. Means were also provided for stopping the car by air cushioned in the end of each section on the closure of the valve, independent of the movement of the train. Such was the construction of the celebrated atmospheric railway of 30 years, or thereabouts, ago, lines of which were laid, as previously intimated, in France, between Paris and St. Germain, and in Ireland between Kingston and Dalkey, and which, in one instance where the leading vehicle of a train became accidentally detached, showed its capability of propelling a single car at the rate of 70 miles an hour.

The difficulty of keeping the tube or main with its longitudinal valve, in perfect working order, having been quite manifest in the comparatively successful experiments of Clegg and Samuda, and much more so in those of Finkus, it was natural that some appliance other than the valve should be sought for in order to communicate pneumatic power from the stationary engine to the travelling car. It was doubtless this that, in 1844, led Pierre Armand Fontainemoreau to propose a pipe or main laid lengthwise of the track, and either kept filled with air under pressure or subjected to the action of an air pump to maintain therein a vacuum more or less complete. In the former case the main was to be furnished at intervals with valves opening inwards. The locomotive was provided with two cylinders properly arranged in relation to the driving axle, and furnished with devices which automatically operated the valves in the main to supply the cylinders with compressed air, in the same manner as those of an ordinary locomotive are supplied with steam from the boiler. In the event of using a vacuum in the main, the action of the engines was simply reversed, air being exhausted from in front of the pistons, so that the latter would be operated by the direct pressure of the atmosphere. So far as we know, no practical trial of this was made, but with the addition of a tank to receive a supply of compressed air in lieu of feeding the engines direct from the main, Fontainemoreau's plan might stand as the type of one of the subdivisions of the third class of pneumatic motors; for this class includes three sub-systems—that in which the air is compressed in a main extending the whole length of the line, and calculated to supply the air to the locomotive tank automatically and without stopping the train; that in which a similar main is proposed, but the cars stopped for the temporary connection of the tanks; and

that in which a separate compressing power and compressed air reservoir is provided at every station. The first of these, from its theoretical completeness, is apt to please the fancy of projectors, but, from the extreme accuracy required in the fittings, will probably never prove practically successful. The second has the merit of concentrating the power in few places along the route, and of requiring but a minimum of attendance, but involves the necessity of keeping an extremely great volume of air constantly compressed. The third—although multiplying the number of engines and reservoirs—will, all things considered, probably meet with the most favor when this method of storing up power for car propulsion is tested as its merits, theoretically at least, deserve.

In further reference to each of the three classes of pneumatic apparatus sketched in the earlier portion of the present paper, it is necessary to consider in each the degree of utility thus far attained with it; the most feasible methods of obviating its defects; and the conditions under which it may be most advantageously adapted to the needs of travel in New York city. For whatever, in this line, can be made practically successful under the drawbacks encountered in the metropolis, need excite no apprehensions of failure in any other locality. First in importance, as in the date of its original conception, is Medhurst's earliest scheme, known of late years in England as Rammell's system, from its—in recent times—most prominent advocate, and illustrated in this country by that fragmentary undertaking, the pneumatic tunnel under Broadway, which, with a passenger car running a distance of 300 ft., has confirmed, on this side of the ocean, the favorable expectations induced from Rammell's experiments, in 1861, with baggage trucks driven a quarter of a mile through a cast-iron tube or tunnel of 2 ft. 9 in. in height, and a width of 2 ft. 4 in., narrowed at the bottom to 2 ft. 2 in. This line was worked by the partial exhaustion of the air in front of the car, and, with a pressure behind of from 4 to 6 oz. to the square inch, a speed of 25 miles an hour was obtained. Four years later, the completion of the tunnel from Holborn to Euston, 1¾ miles afforded opportunity for more complete, definite, and decisive trial. This tube in its cross section was of horse-shoe form, 4 ft. 6 in. high, and 4 ft. across. In lieu of the longitudinal shoulders which, in the experimental line, had been made to do duty for rails, common wrought rails were employed, fixed upon suitable bed timbers arranged lengthwise under them. The goods trucks weighed each 1½ tons. A train of 4 trucks with an aggregate weight of 10 tons was forced through the tube with a blowing pressure of 5 or 6 oz. per sq. in., or a vacuum equal to about 1 oz. less, and this at a speed in no degree inferior to that obtained in the previous or purely experimental trials. The expense of transport for freight was found by careful calculation to be less than 1 penny, or 3 cts. per ton per mile, including interest on cost of engine, wear and tear, fuel, attendance, and incidental work in the establishment. About the same time another trial on a large scale was made with a brick tunnel 600 yards long, 9 ft. in height, and 8 ft. in width. The carriage was fitted with a fringe of bristles reaching nearly to the brickwork to reduce windage, and the 20-ft. fan by which the blast was furnished was driven by an old locomotive engine jacked up, and with belt-wheels substituted for its drivers. Only a small portion of this line was level; it had at one place a gradient of 1 in 15, and curves of only 8 chains radius. The car traversed the whole distance in 50 secs., with an atmospheric pressure of 2½ oz. to the square inch. On the whole, without adverting to more extended or more recent trials, it may be assumed that, years ago, experience demonstrated the feasibility of propelling cars through tunnels by atmospheric pressure at from 20 to 40 miles an hour, while theoretically by the use combined of an air-blast and vacuum, the probability of securing a speed nearly or quite twice as great is apparent. But in the running of cars for a distance equal to that between the upper and lower parts of Manhattan Island, numerous details would require to be worked out and adjusted to secure the practical success of the system. Among these would be that of arranging for the stoppage of one car or train without interference with others in motion along the route, and which in the use of a vacuum would necessitate the adoption of a plan equivalent to the valve-separated sections of Clegg and Samuda in their otherwise quite different plan. It is true that, by

the use of an air-blast, only, a continuous line of cars might be propelled by what might be termed the air cushion throughout the length of the tube, but in the event of the stoppage of the foremost on the line, danger of collision from those behind would be imminent. It is possible that modifications of the turnouts applied in pneumatic tubes for the transmission of parcels could be applied in those for passenger transit. That of Needham, an American invention, brought forward during the past few years, comprised a circuit tube, with ends connected at a suitable distance apart with the main or transit tube, and used in connection with valves which shut off, in the space between the ends of the circuit tube, a portion somewhat longer than the carrier or piston. One of the valves was shut in front until the carrier, cushioned by the air in front, was stopped. The other valve in rear was then closed, the blast being thus directed through the circuit tube around the inclosed portion of the main tube. The top of such portion, hinged for the purpose, was then opened to admit access to the carrier. With the circuit tube entering the main at a slight angle, and with automatic switch-operating mechanism to shift the rails, there seems no good reason to doubt that, by means substantially like those just detailed, cars in an 8 or 10 ft. pneumatic tube could be stopped at stations without interfering with the continued passage past of cars previously behind them in the tube.

The points to which reference has just been had wherein the development of improvements is still required are not so abstruse as to leave any doubt as to the practicability of securing them, neither can there be much doubt as to the conditions, and the sole conditions, under which the system can be applied in New York and other cities. That pneumatic tunnels of only a few feet diameter, dark in spite of gas jets, and damp in spite of the ever fresh current of air, are not adapted to popular needs and wishes, is shown by the fact that the projectors of the Broadway Tunnel are already agitating for the privilege of making a tunnel 30 ft. in width, in which this plan of pneumatic propulsion will prove inadmissible. That its use on the surface is out of the question is manifest at a glance. There remains then only an elevated railway as affording an opportunity for its use, and with such it would prove superior to any other method of propulsion yet suggested. Let an elevated pneumatic tube be carried over the buildings and cross-streets, sustained on iron supports constructed on the principle of a suspension bridge over each block; let this tube be of wrought iron for strength and lightness; lined with wood for moderate warmth and for reduction of friction to the air-blast; glazed throughout its length with panes of sufficient size and numbers to light it well; furnished with turnouts, to enable one car to be stopped at every station without interference with the others; furnished with electric signals automatically actuated by the cars themselves, to indicate their approach to the stations; and place the working of the line, from the lowest duty to the highest, in the hands of educated, careful and properly remunerated engineers, and the question of quick transit, in one of its phases at least, will be solved with greater satisfaction to the public and credit to the engineering profession than the most ardent advocates of speedy passenger travel now dare hope for. The lighting of the tube by windows, which would constitute a most essential element of success, would not, as might at first appear, be a matter of much practical difficulty. Although brittle, glass is comparatively strong, and would resist many times the pressure required to be brought upon it in working the line. An example, apropos in this connection, of the ability of glass to resist pressure, was given some years since in steam-boiler experiments of the Franklin Institute, in which the plate-glass window of a boiler withstood the pressure until it rose suddenly to 180 lbs. to the sq. in.

Allusion has already been made to the proposed supersession of the present Broadway tunnel of 8 ft. diameter by one 31 ft. in width, 18 ft. in height, and furnished with double tracks. In the plans made public, no information is given as to the motive power proposed, but it is manifest that cars running in opposite directions could not, unless the tunnel be longitudinally partitioned from end to end, be propelled by the fan-blast or exhaust used in the present experimental work. It is hardly likely that the folly of wire ropes will be repeated in this case,

or that the slow power of horses will be used on a railway built at such cost. Locomotives may be attempted, but their employment, because of smoke, foul air, and jar to the foundations of buildings, should not be tolerated. The motive-power for such an underground line is not of less importance than the construction of the line itself, and the latter should, from the first, be calculated with especial reference to the former. Although the suggestion is not free from difficulties, there is good reason for the belief that the Clegg and Samuda system, a tube with a longitudinal valve-covered slot in the top, and an internal piston connected with the car running on an external track, would effectually subserve the purpose of transit through such a passage way under the streets. During the existence of the line between Kingston and Dalkey, a gross load of 50 tons was at times propelled at a speed of 50 miles an hour, the gradient being 1 in 115, the diameter of the main 15 in., the vacuum at the greatest equal to 25 in. of mercury, and the engine of 100 horse power. The leakage of the valve absorbed about 10 horse power per mile, or 30 horse power per section of 3 miles. The cost of such a railway, laid on the surface, was about $25,000 per mile, at the price of labor and material a quarter of a century or more ago. The loss of power by leakage through the valve appears to have amounted to from $\frac{1}{4}$ to $\frac{1}{3}$ of the whole. But this, while serious when in direct competition with locomotives, would be of minor consequence when the great patronage of a New York city railway warranted unusual outlay, and, as far as the ventilation at the tunnel is concerned, would prove a positive benefit to the line, though at the cost of fuel for the engine. It must be remembered, too, that the valves devised by Clegg and other projectors of his time, were, before the introduction of india-rubber, a substance better than any other adapted to such a purpose. There is apparently no good reason why a strip of caoutchouc so applied as to press laterally over the longitudinal opening in the tube, should not serve in a much more efficient degree, all the functions of the complicated device of Clegg and Samuda's railway. Should it prove too slight in tensile strength, a wire rope could be imbedded within it, and should its yielding power be found insufficient, this essential could be increased by giving a cellular consistence to the material by methods already known. The deterioration which would occur from contact of oil or grease necessarily used for lubrication, would, in the use of India rubber as just indicated, require that it have cemented upon it a covering of leather or the like.

While there can be no doubt that both an elevated and an underground railway, properly constructed, will meet with the most extended and profitable patronage from the citizens of New York, there is no reason to suppose that the surface lines will ever be given up, and on them some motive power other than horses or steam should be provided. Of the several systems of pneumatic propulsion, that which embraces tanks of compressed air, serving in lieu of steam in the driving of engine pistons, is the only one adapted to the purpose. A number of trials have been made during the past few years with alleged satisfactory results, but it is doubtful if the chief obstacles to its employment at all seasons of the year have been overcome. Among recent inventions designed to increase the utility of the system is one in which the tanks are to be made of paper, obviously to prevent as far as possible the loss of power by radiation of heat generated from the compression of air in the tanks; another covers the use of a number of cylinders connected by tubes to form together the compressed air reservoir of the car, and which admits of a more convenient arrangement of, as well as greater strength in, such reservoir. The inventor of this also claims the combination with the heating apparatus of the car of a conducting pipe from the reservoir in such a way that the compressed air, while passing to the engine, may be heated to increase its expansive power, while still another feature of his apparatus is a muffler or box lined with soft fibrous material, to receive the exhaust from the engine and deaden its sound.

The plan of making the reservoir of non-conducting material might possess a certain advantage if the air could be used as soon as compressed, or before time for any considerable radiation has been afforded. The arrangement of the air-holding cylinders in connection with each

other would afford in some cases a source of convenience, but would not be essential to the arrangement of the cylinders with regard to economy of space, as the cylinders might, in succession, be brought in communication with the engines. The need of the muffler seems doubtful, and, as the air could hardly leave the cylinders quite reduced to atmospheric pressure, it would probably be much better to throw the exhaust into the car-heating furnace in winter to urge the blast, and in summer into the body of the car to cool the atmosphere therein. The heating of the compressed air to increase its power of expansion would be likely to be of advantage only when incidentally incurred in protecting the cylinders from the congelation of vapor contained in the air, and liable to be frozen by the absorption of heat by the expansion of the air in working the engine. To this end, it would be advisable to arrange the cylinders within annular jackets in open communication with the furnace used for warming the car, and which should be constructed with especial reference to this use in connection with the driving motor. This last should furthermore be so applied in connection with the brakes, that the throw of a lever would instantly turn the pneumatic power from the propulsion of the car to its stoppage, which, by this means, could probably be accomplished in less time and within a shorter space than could be done with horses at an equal speed. There is in addition to those just specified another point which is now beginning to attract the attention it deserves, viz., the regulation of the inflow of air to the cylinders. This has been accomplished, it is claimed, by very simple devices, and, indeed, the mechanism need not be complex, for the connection of the stem of a pressure-gauge with a valve governing the size of the cylinder inlet-ports would seem to fully embrace the principle of an efficient device for the purpose.

The elements enumerated as essential to the success of the system will necessitate the construction of a street car radically different from those now in use, especially in the matter of weight. But there should be no difficulty in reducing the weight of the car, so as not to exceed, with its engines and reservoir, 9,000 lbs., the weight of the clumsy vehicles that now traverse the tramways of New York.

In conclusion, such in brief are the ideas of the writer on the most important application yet suggested of so-called pneumatic power. As to how far they will ever reach fruition in the solution of the vexed question of city transit, it is impossible to say. But they have been deduced, without reference to any especial plan or theory, from the actual results of recorded practice, not less than from the well-known laws of science, and have led him to believe that passengers may be cheaply carried to and from the City Hall at from 20 to 40 miles an hour with all the comfort of ordinary railways, and none of the dangers or inconveniences incident to the employment of locomotives.

SWISS METHOD OF DRIVING PILES.

From Professional Papers of the Corps of Royal Engineers.

During a tour in Switzerland, the following method of driving piles was seen being successfully employed at the town of Visp, after an inundation of the river of the same name.

The inhabitants required a bridge over a rapid and shallow river of about 5 or 6 ft. in depth, and 80 to 100 yards in width. Moreover, as traffic was suspended until the bridge was completed, celerity was of the utmost importance.

The bottom of the river was composed of stones and fine sandy silt, such as is generally washed down from the Swiss mountains during heavy rains. A bridge on small piles was adopted as a temporary plan to restore the diligence route during the repair of the old retaining wall of the river. The method of driving the piles, which was new to me, seemed so efficient that I reported upon it to Major-General Sir John Simmons, C.B., R.E., on my return to England.

The piles used were about 12 ft. long, and 5 in. in diameter; the bottom of the pile was merely pointed, and was not shod with iron, neither was the top protected with a ring or other contrivance to pre-

vent the pile splitting. A $\frac{3}{4}$ in. hole, about 9 in. long, was bored in the top of the pile, and a $\frac{3}{4}$ in. iron bar, 6 or 7 ft. long, was driven into this hole, and acted as a guide bar on which the monkey slid. The monkey consisted of a piece of round oak, about 10 in. in diameter, and 30 in. long.

It had a strong bond ring at each end, and through its central axis was an inch hole from end to end, in which a guide bar could easily slide.

There were four bent handles of bent ash, projecting from the body in the arc of a circle, and fixed to it under the bond rings. There were also some smaller monkeys with only three handles.

The men who worked the monkey stood round it, and worked it vertically, taking time from the leading hand, who gave a lusty shout when they were to heave; after lifting it as high as they could, they assisted the fall by a strong vertical downward pull. Sir John Simmons allowed me to make some experiments in the fieldworks at Chatham, and to form a pile bridge, by driving the piles in the manner above described. The monkey used consisted of a piece of round oak $9\frac{1}{2}$ in. in diameter, and 3 ft. 6 in. long, and it had a central hole $2\frac{1}{2}$ in. in diameter, bored from end to end, and then burnt out to get a smooth surface.

It had four handles, made of $\frac{3}{4}$ in. round iron; they were flattened out at the ends, and a hole made through the flattened part, by which a wood screw fastened the handle to the monkey, the wood being slightly cut away at that part, and the outer part of the handle thus brought flush with the surface; a shoulder, however, was left on the handle to butt against the bond rings. The bond rings were made of $\frac{5}{16}$ in. iron, and were 2 in. broad. They were shrunk on after the handles were attached. Much difficulty was found in making the wooden handles stand the shock of the concussion; but after iron handles, as described, were used, no further trouble was met with. As the $\frac{3}{4}$ in. handles were rather small for the hand, they were served with spun yarn.

I was anxious to devise some method by which the platform, upon which the men who worked the monkey stood, should be fixed to and supported by the pile itself, so that their dead weight should push the pile deeper after the blow had moved it and disturbed the mud and earth surrounding it.

I tried several plans, and when $\frac{1}{4}$ in. iron plate can be procured, and a forge and a good smith are at hand, the best seemed to be as follows:—

The platform itself was of wood, formed of planks and battens; it should be circular in shape, and should have a central hole large enough to take the largest pile that is to be driven.

This was supported on two clips of iron which were cut out of $\frac{1}{4}$ in. plate, bent to a right angle, and again bent at the centre to receive the pile; two of these were then riveted together by similar arms to form one clip, the other two arms being drilled with suitable holes for screw bolts which attached the two clips firmly together, and caused them to grip the pile.

When the platform was about 15 in. below the top of the pile, the men could work with the greatest force.

Should there be no forge at hand, the following method can be resorted to if the piles have not to be driven to a greater depth than 4 or 5 ft.

Two planks 20 ft. long, 3 in. thick and 12 in. broad, had each a hole bored through the centre at a distance of 1 ft. 7 in. from the ends and a diamond-shaped jaw 9 in. long and 5 in. broad, was made at a distance of 2 ft. 2 in. from one end; the ends of the planks were connected together by 4 turns of No. 8 iron wire, which passed through the holes at the ends near the jaws; the other ends were connected by a lashing after the planks had been lifted over, and their jaws had embraced the top of the pile to be driven. In order to prevent the planks slipping down the pile, a lashing was tied around the latter about 15 in. from the top, and some strong iron spikes driven in below the lashing; and to prevent the planks toppling sideways, an iron hanger was made. This could be replaced with wire or small strong rope from the pile top to the outside of the planks, where it could be fastened to a projecting batten, or to spikes suitably placed.

The plan that seems the best for bringing the piles into position is as follows: The length of bay should not exceed 10 ft., and it is easier to work with a bay of 8 ft. Two strong poles about 20 ft. long and 5 in. in diameter, are bolted together at one end about 7 in. apart; they are

then lashed down to the last bay; 2 planks are laid on them and the pile taken out point foremost and dropped into its place. A small cross piece is then lashed on the ends of the spars to prevent the pile falling outwards. The iron clamp and circular platform, or the plank platform, is then put on, and the guide rod and monkey brought out and placed on the pile by two men; the remainder then follow, and the pile is driven until the bottom of the platform is brought down to the poles. The driving party then come in, bringing with them the monkey and guide rod; the platform is next brought in, and the transom and rod-bearers are duly lashed in their places.

EXPERIMENTS.—A Norton's tube-well was driven 14 ft. in less than half an hour.

Short piles, 6 in. diameter, were driven in hard ground at the rate of 18 in. per min., a platform clamped to the piles being used to carry the driving party of four men.

A pile bridge 90 ft. long and 10 ft. wide with bays 12 ft. or 13 ft. long, was made by 10 sappers in 41 hours of actual work. The average weight of each pile was from 90 to 100 lbs., average diameter 6 in. top and 4 in. bottom, average length 20 ft. The nature of the bottom in which the piles were driven, was 12 in. of mud, and a thick layer of gravel. The weight of the monkey being a little more than 1 cwt., it will be seen that the piles were rather heavy; nevertheless they were driven at an average rate of 1 ft. in 4 or 5 min., and sometimes as fast as 6 in. per min.

Sir John Simmons proposed that a lengthening tube of Norton's tube-well should be used as the guide bar; it was tried, and answered the purpose admirably. It was found to be important that the hole bored in the top of the piles to take the guide bar should be quite vertical when the pile was being driven, otherwise the friction between the monkey and the bar was apt to pull the latter out of the hole.

It was found that there was no necessity to bind the tops of the piles to prevent them from splitting.

The men preferred working on the platform with iron clips, as they had more room and a more stable footing; with the plank platform, also, some difficulty was experienced in lifting the heavy planks over the head of the pile. The time necessary to get them into position was nearly the same.

STEAM ENGINE CYLINDERS.

From "The Engineer."

The correspondence which has recently appeared in our pages on the subject of jacketed cylinders affords ample proof that much has yet to be learned about steam engines even by otherwise able and competent engineers. Any one favored with opportunities for acquiring information concerning what is being done by the most successful firms, will soon discover if he think proper, that even when excellent results are obtained as regards economy of fuel, they are but too often got by the application of the rule-of-thumb system to in one sense very recondite problems. It was discovered as far back as Watt's time, that by keeping a cylinder hot, less fuel was required to do a given amount of work than sufficed when the cylinder was cooled down by sending injection water directly into it. The separate condenser got rid of the injection water; but it was soon perceived that this was not enough, and the steam jacket was added with advantage. Almost every engineer knows nowadays that a cylinder should be kept as hot as possible; but very few makers of steam engines understand the precise reasons why a cylinder should be kept hot. If questioned on the point, they say glibly enough: "If you don't keep it hot the steam is condensed and wasted;" but in almost all cases the belief is held that the dreaded condensation takes place by conduction through the substance of the cylinder to the outside. Of course there are men who know better, but we are not speaking now of particular firms, but of the great mass of engine makers, who, if they used jackets at all, use them with but a dim glimmering of an idea concerning the principles on which they operate for good. We have explained and re-explained the action of the steam jacket and the

phenomena which occur within a cylinder, we hope with benefit to some individuals; but it is none the less certain that we may now treat the subject from a slightly different point of view without saying something that every one is sure to know all about beforehand.

Let us see how much steam it is possible to lose by leaving a cylinder and its appurtenances absolutely unclothed. We may for practical purposes regard the cylinder under such circumstances as an air surface condenser. Peclet, our great authority on these questions, shows that if a current of air at 59 deg. Fahr. be suffered to flow over cast-iron tubes, steam will be condensed within them at the rate of 0.36 lbs. per sq. ft. per hour. The cylinder of a steam engine is a tube, and air circulates round it because, being warmed by the heated metal, it continually rises and is replaced. Now a fairly good engine will give one horse power indicated for every 30 lbs. of steam passing through it per hour. On Peclet's data, the quantity of surface required to condense 30 lbs. of steam per hour would be 10.8 sq. ft. To be on the safe side, however, and to eliminate fractions, we shall suppose that every 10 ft. of unclothed surface represent a loss of 1-horse-power indicated per hour. Let us see how this fact will apply in practice. The cylinder of an 8-horse portable engine is, we will say, 9 in. diameter. The piston stroke is 14 in. Then the surface exposed by the cylinder, valve chest, lids, etc., will not be far short of 6 sq. ft. The loss incurred therefore by not clothing the cylinder as far as external cooling is concerned, will amount to about .6 of a horse-power per hour, and this loss will be approximately constant whatever the weight of steam passed through the engine. As, however, .6 of a horse-power bears an appreciable proportion to the power likely to be developed in such a cylinder, it is worth while to lag the cylinder carefully, by which the loss will be reduced to a mere nothing. Let us turn now to an engine of, say, 250-horse power nominal. We shall allow as before 10 circular inches of piston per nominal horse. In other words, the cylinder will have a diameter of 56.5 in. nearly. Let the stroke be 8 ft., a common proportion. The cooling surface of such a cylinder with its appurtenances would be about 170 sq. ft., which would suffice to condense about 17 horse power of steam per hour. If the engine indicated 500-horse power the loss would therefore be very nearly $\frac{1}{30}$th of the whole work done. If the portable engine worked up to 16-horse power, the loss would be nearly $\frac{1}{26}$th. It is more probable, however, that the large engine is worked to three times, than it is that the portable would be worked to twice its nominal power. It is evident, in any case, that small cylinders require to be more carefully clothed than large cylinders. Clothed or unclothed, however, no conceivable theory based on the passage of heat to the outside of the cylinder will account for the enormous condensation which takes place in unjacketed engines expanding steam more than two or three times.

We have before now shown that if it were possible to construct a cylinder of perfectly non-conducting materials, we should have the nearest possible approach to a perfect steam engine. The temperature of the cylinder would have no effect whatever on the steam, if the metal were absolutely incapable of absorbing heat. The action in such a cylinder would be as follows:—Saturated steam would enter from the boiler at the beginning of each stroke. As work was performed a portion of the steam would be condensed, and as expansion proceeded the temperature of the steam would fall, but no condensation would take place, as a consequence of expansion alone; on the contrary, as the total heat of steam slightly augments with each rise in pressure, steam, when suffered to expand without doing work, becomes sensibly superheated. As, however, in the case under consideration, condensation would take place, because the loss due to the performance of work greatly exceeds the trifling gain proper to expansion, it follows that a small quantity of water would probably be deposited on the sides of the cylinder, piston, etc., but not much, because the condensation proper to the performance of work taking place through the whole body of the steam, the water would be held in suspension and carried off to the condenser. The indicator curve would be lower than that proper to Marriotte's law by an amount measured by the condensation and consequent reduction in the volume of steam, caused by the performance of

work. At the end of the stroke the steam would rush to the condenser, but no re-evaporation of water deposited on the sides of the cylinder would take place other than that proper to the sensible heat of the deposited moisture. When the return stroke was complete, and steam was admitted for the second time, it would find the cylinder in precisely the same condition as at first; there would be no condensation due to cold surfaces, and so the process would proceed, and the maximum economical result would be obtained. Now, in practice, it is impossible to obtain a cylinder which is an absolute non-absorbent of heat, but we can bring the metal of which it is composed to such a condition, that it may be regarded as perfectly neutral. It is well known that when two bodies have exactly the same temperature, no interchange of heat will take place between them. If, therefore, we heat the cylinder to precisely the same temperature as the entering steam, no condensation will take place. The metal may be regarded as neutral, and the action will be just the same as that in a perfectly non-conducting and non-absorbing cylinder. We can reduce the cylinder to this condition by the application of a jacket. If the engine worked without expansion, no transference of heat from the jacket to the cylinder would take place, except that due, first, to the fact that the steam within the cylinder would fall a little in temperature owing to the performance of work—and even this effect would probably only take place because it is impossible to work an engine without cutting off communication with the boiler before the stroke is complete; and, secondly, because the cylinder, being opened to the condenser at the end of the stroke, its inner surface would be made cooler than its outer surface; consequently heat would be transmitted to the condenser from the jacket. If, however, the interior of the cylinder were quite dry—as it ought to be—the loss from this cause would be very small. It is certain, however, that a considerable quantity of steam is condensed in all jackets beyond that which can be accounted for by the work done; and this is no doubt due to the fact that the metal of the cylinder is kept, necessarily, at a temperature intermediate between that of the jacket and that of the condenser, though nearer to the former than the latter. Just at the end of the stroke the inner surface of metal is so far cooled down that even when the jacket is used a small quantity of steam just entering is condensed. This is not re-evaporated until near the end of the stroke, and then it is done at the expense of the steam in the jacket, and it acts especially injuriously in that it wets the steam flowing to the condenser, and thereby renders it a good conductor. It must not be forgotten that heat takes some little time to traverse the sides of the cylinder. It is quite possible, therefore, that a sudden rush of wet steam at the opening of the exhaust may reduce the temperature of the inside face of the cylinder very considerably, and before heat can reach this surface again from the jacket, the steam port opens, and the fresh steam comes at once in contact with a surface some degrees colder than itself. Water is deposited, and has to be re-evaporated at the expense of the jacket, and so represents a dead loss, in that it has been twice evaporated and done work but once. From this it appears, first, that the sides of the cylinder should be made as thin as possible; and, secondly, that they should be of good conducting material. It may be urged that, under these conditions, the condensation in the jacket will be increased because of the influence of the condenser during the exhaust; but this argument has no force. If we but keep the exhausting steam and the sides of the cylinder, etc., dry, there will be no sensible loss. Experience has proved that practically no condensation occurs in a jacket when the engine is kept standing for long periods at the end of its stroke, communication being freely open between the cylinder and a condenser holding a good vacuum. Paradoxical as it may seem, the best way to prevent useless condensation is, as we have said, to make the material of the cylinder as thin as practicable and of the best possible conductor.

There is a practical objection to the use of the jacket to which we have not yet referred. High-pressure steam, especially if quite dry, appears to exert a peculiar solvent effect on cast iron. Already we hear rumors in numerous directions of the rapid wear of the high-pressure cylinders of compound engines, an evil which grows in proportion with each augmentation of

the weight of the casting. It appears to be fortunate that the remedy for this evil affords the best possible method of applying the true theory of the jacket in practice. In certain cases the jacket is made by putting a thin steel tube into a cast iron cylinder bored out to receive it. The Reading Works Company have brought this system of construction to great perfection, for example, with excellent results. How far the scheme is applicable to marine engines we are unable to say. We suggest that, especially in marine engines, instead of steel—notably an uncertain material—hard brass, or, more strictly speaking, gun-metal liners should be used for the high-pressure cylinders. Properly made the material is much harder than cast iron, and will take a beautiful surface; while the material being an excellent conductor, would comply with one of the fundamental conditions of eminent success in using the jacket. The idea is a mere extension of the system of lining air pumps. We do not claim it as original, but we believe this is the first time the scheme has been mentioned in any journal; and it appears to us to be well worth the consideration of engineers engaged in the construction of large steam engines working with considerable pressure.

THE LIVING FORCE OF COMPRESSED AIR.

By Mr. PERRIGAULT.

Translated from "Les Mondes."

The velocity of a jet of condensed air escaping from the base of a fan is determined by means of the formula

$$v = \sqrt{2\,g\,h};$$

v being the velocity, and h the height obtained by dividing the effective pressure P by the density d' of condensed air, deduced from the pressure in the reservoir.

But if the formula $d'\,h$ or $\frac{1}{2}\,m\,v^2$ is employed in determining the living force of a cubic metre, we get only the measure of the living force produced by a non-elastic fluid of density d', without finding the value due to the elasticity of compressed air.

To determine the total mechanical effect, we must employ another height, H, equal to $\frac{P}{d}$, d being the density of air before compression, under the hypothesis that the work is effected without any loss of the heat generated by the condensation.

Suppose, for example, we take 1 cubic metre of air at the temperature of 112°, $25-112$, $25\,d = 1^k.293 \times 1 - 0{,}003665 + = 1^k{,}822$.

We condense the cubic metre to 2,994 at m absolute. In this condition it would equilibrate a column of water 20600 m/m high.

$$H = \frac{20600}{d} = 11306 \text{ metres}$$

The number of heat-units produced, admitting that the mechanical equivalent of a unit is 425 kilogrammetres is

$$\frac{11306}{425} = 48^c\,47.$$

The increase of temperature, supposing that 0°,237 raises 1 kilogramme of air 1 deg., is

$$\frac{48^c.47}{0{,}237 \times 1{,}822} = 112°{,}25.$$

The volume under pressure becomes

$$\frac{1 \times 1 + 0{,}003665 \times 112°.25}{2{,}994} = 0{,}471 \text{ litres.}$$

The cubic metre of this air, so condensed, would be composed of 2 cubic metres 123 litres of non-condensed air at the temperature—112°,25; and the density would be

$$2{,}822 \times 2{,}123 = 3^k{,}87.$$

Finally, the total work stored up in one cubic metre before compression would be $T\,r = H\,d$; after compression, $T\,r = H\,d'$.

I have made use of this high pressure of 1,994 at m., a pressure not realized in fans, in order to compare the results of the above calculation with those obtained by M. Tresca in the remarkable experiments made by him.

On the 12th February, 1865, he condensed air in a condenser of the capacity of 3 mc. 208 litres. The effective pressure was 1,994 at m., or 20,600 mm. of

water, and the temperature after compression was zero. He allowed the condensed air to escape by opening a valve 10 times, keeping it open a very short time, generally about 5 sec. At each discharge he restored the temperature.

Before the first discharge the monometer indicated a pressure of 2,275.51 of mercury ; and after the last discharge, 0,823.90 *m.*

The useful expansion was, therefore, 1,451.61 *m.* of mercury, or 19,730 *mm.* of water, the total pressure reading 20,600.

The temperature rose to 102°,18. But it was remarked that during the time of each discharge the reservoir imparted to the air contained in it an appreciable quantity of heat, and that this emission would diminish 5 per cent. the lowering of temperature, which, under these circumstances would have reached 107°,289.

The density of the compressed air was 3.87 *k.* The cooling being proportional to the pressure, we can determine the fall if the expansion were equal to the atmospheric tension, by means of the proportion 19,730 *mm.* of water : 107°,289 : : 20,600 : x=112°,02. Let us now compare the results of our calculation with those of M. Tresca. Proceeding in an inverse manner, we take air compressed at 1,994 at *m.* and allow it to expand. The original temperature was 107°,289 for an expansion of 10,730 *mm.* of water. Hence, if the expansion had been 20,600, the temperature would have been 112°,02.

Is it possible to justify a method of calculation by a more confirming experience ?

The first consequence is that the mechanical equivalent of heat appears to be precisely 425 $k. \times m.$

The second, is that a cubic metre of air at any density, when compressed to a tension P measured in *mm.* of water, will develop $\frac{P}{425}$ heat units, and that its temperature will rise from $\frac{n\,c}{d}$ degrees n heat units. The work stored up will be $\frac{P}{d}$. The living force of a cubic foot of air compressed by a column of water will be equal in kilogrammes to the number of millimetres of the column which is the measure of compression for a cubic metre, measured before compression.

H *d* expresses the total work of the jet of a cubic metre condensed, measured before compression.

H *d'*, after the compression.

h d, and *h d'*, are the work without expansion.

The expansion of a jet of air, or the dynamic expansion, is H $d' - h\,d'$ measured at the bottom of the fan. This differs essentially from the expansion in the air.

CHARLES BABBAGE, PHILOSOPHER.

From "The American Exchange and Review."

"LONDON, Oct. 21. 1871.—Charles Babbage, mathematician and philosophical mechanist, and author of several mathematical works, died yesterday, aged 79 years."

When we read in our morning paper the above despatch by the Atlantic cable, a host of impressive memories rose to our mind, and have been haunting us ever since. For, from boyhood to the present day, the wonderful works of this man have had for us a fascination and a delight. We have come to think of him as of a much prized old friend, and we feel almost a sense of personal loss at his death, a feeling intensified by the knowledge that it is rare to find thought so clear and profound as his, united with such skill in embodying its results in useful art.

He was not well known to the present generation ; but 30 years ago, Babbage's calculating machine was an object of interest to the ingenious and of curiosity to the uningenious of both continents. That this interest and this curiosity have now almost died out, that frequent newspaper items no longer stimulate them, that the incomplete machine itself rests in unnoticed obscurity—these things, we believe, indicate not that his inventions were useless, only that they have not been properly used. This we shall make some attempt to explain.

The calculating machine was intended to construct mathematical tables. To most readers this may seem of comparatively little moment in a practical point of view.

Those who are unaccustomed to use tables cannot form any adequate idea of their value. They know that there are such things as tables of logarithms, and of sines, tangents, and secants; they may have learned how to use them at school, but they do not regard them as having any relation to their every-day lives; they do not know how intimately they are interwoven with our houses and furniture, our clothing and food. Yet in so far as any of these things depend on commerce, there is the most direct connection. The navigator determines his longitude by observations of the moon's distances from the sun, the principal planets, and certain conspicuous fixed stars. Long and laboriously calculated tables tell him the positions of these stars at Greenwich; and then, by certain calculations involving several other tables, he infers his own position and can tell how to direct his course. No less than ten numerical tables peculiar to each star are required to predict its exact position; and as the mariner is furnished with tables for 100 such stars, 1,000 such tables are constructed. These 100 stars, however, are not as many as could be desired, considering the wide range of the moon through the heavens, particularly as an accurate method of determining the longitude consists in observing the occultation of a star by the dark edge of the moon. There are at least 1,000 stars so situated as to be at some time in the moon's path, and to exhibit these desirable occultations. To predict these all would require 10,000 tables. The stars from which lunar distances may be taken are still more numerous. It may safely be said that the nautical almanac does not now furnish more than a small fraction of that aid to navigation which it might be made to supply with greater facility and accuracy in the construction of tables. We have mentioned here only one class of its tables. There are others of almost equal extent and importance. And when we leave navigation and come to surveying, mining, engineering, and in fact almost every department of commerce and the useful arts, the number of tables required swells to formidable proportions. Still more is this the case in more purely theoretical science. In astronomy their name is legion; as natural philosophy approaches perfection, they enter into its records in a continually increasing ratio; and they are beginning to swarm in chemistry and meteorology. Considering, then, the infinite number of delicate connections which we can trace between the theoretical and the practical in our progressive civilization, and the infinite further number whose existence we have reason to infer, though we cannot perceive it, we may form an estimate of the high importance of having these tables readily and accurately calculated.

We say accurately as well as readily, for the human mind is unreliable as well as tedious. Nothing but the unerring motion of well made machinery can be trusted. Civilized governments have expended millions of dollars in employing the highest mathematical talent for the construction of the most important tables, yet hundreds of errors have crept into the best of them. Mr. Baily detected more than 500 in the solar and lunar table from which the English nautical almanac had been for a long time computed. Another mathematician detected 1,000 in some tables published by the Board of Longitude for finding the latitude and longitude at sea. In a mere multiplication table extending to 100 times 1,000, computed by Dr. Hutton for the same board, a single page was found to contain 40 errors. And some tables which they published for the correction of the observed distances of the moon from certain fixed stars are followed by a table of acknowledged errata, extending over 7 folio pages. But even this latter table is not correct; a considerable number of errors have been detected in it, so that errata upon errata have become necessary. Even if tables are independently calculated by several persons, it is found that certain kinds of errors are likely to be made by all.

Now, although the mathematical formulæ on which tables are based, are many of them of the most abstruse and complicated nature, it happens that a comparatively simple process, called the method of differences, can nearly always be used in their computation. We shall endeavor to illustrate this method in one of its simplest cases.

Let us take the increasing series representing the number of cannon balls in a triangular pyramid. The numbers are 1, 4, 10, 20, 35, 56, etc., as may be ascertained by experiment, piling up marbles

or other round bodies. If we subtract each of these numbers from the one next after it, we obtain the following series of differences: 3, 6, 10, 15, 21, etc. Repeating the same operation with this series, we obtain a series of second differences, 3, 4, 5, 6, etc. In the same way we find a series of third differences, 1, 1, 1, etc.

Table	1st difference.	2d difference.	3d difference.
1			
	3		
4		3	
	6		1
10		4	
	10		1
20		5	
	15		1
35		6	
	21		
56			

Now it can be proved that in this series, no matter how far extended, the third difference will always be the same number, 1. This being the case, the table may be continued to any extent in the following manner: Take the next third difference, 1, and add it to the last second difference, 6, producing 7; add this to the 21, producing 28; then add this to the 56, producing the next number in the table 84. The operation may be tabulated thus:

Table.	1st difference.	2d difference.	3d difference.
1			
	3		
4		3	
	6		1
10		4	
	10		1
20		5	
	15		1
35		6	
	21		1
56		7	
	28		
84			

So, having started the table, the rest of the work becomes simple addition—addition, too, always beginning with the same number. In most mathematical tables this number is a very small decimal fraction, and does not occur till the fourth, fifth, or sixth order of differences. If, then, machinery for adding be properly contrived, and some means provided of constantly introducing this invariable number, this final difference, whatever it may be, we have Mr. Babbage's difference engine. The constant number may be introduced by the mere notion of a spring, a descending weight, or any other regularly acting force. After being set the machine requires no mental attention whatever, except to record its results as they are successively shown on the dials. If Mr. Babbage had completed it, even this would have been unnecessary; for he had invented and drawn the plans for an attachment by which the results should be printed as fast as they were attained. By particular grooves in the types, corresponding to the numbers shown on the machine, he had even provided that at any given time the engine would not pick up any type but the right one, and would consequently be free from any liability to error caused by incorrect distribution of the types.

The fundamental nature of machinery for adding may be thus explained: Suppose a wheel with the digits 1, 2, 3, 4, 5, 6, 7, 8, 9, and 0, at equal distances around its circumference. Suppose 6 at the top; to add 7, let the finger, or a weight, or any force, turn it seven of the equal parts more. There will successively come to the top, 7, 8, 9, 0, 1, 2, 3. But 13, not 3, is the sum of 6 and 7. How is the 1 ten to be marked? That requires a tens' wheel marked with the same digits as the units' wheel. The units' wheel has a projecting tooth, and the tens' wheel has indentations into which this tooth fits so as to turn the tens' wheel 1-10th of a revolution, Then the tens' wheel marks 1, as the 0 of the units' wheel succeeds its 9, making up 10. The unit wheel goes on, as we have said to 3, making the complete reading 13. Add 8 more. The units wheel marks 4, 5, 6, 7, 8, 9, 0, 1. At the 0 the tens' wheel has been moved again, and now marks 2. We read in all 21. It is obvious that the extension of the same principle to hundreds, thousands, etc., requires only additional labor and repetition of parts. Mr. Babbage's machine would extend its work to 100 places of figures; and when set for multiplication, which, it must be remembered, is only a compendious form of addition, would multiply to-

gether two numbers each containing 50 figures.

Of course, we have here explained the mere elements of machinery for adding. We have described nothing beyond the process of adding the last column of differences. (In Mr. Babbage's engine it might be the sixth, if required.) The main difficulty consists in the transference of the results from one column to the next preceding, *i. e.*, from one set of wheels to a similar set next to it. The units' wheel of the latter set must be moved not only through as many unit spaces as the one preceding it—this would be easy—but each time through as many as are indicated by the continually increasing *results* arrived at in the former. Thus, suppose that at a certain stage of the process, when the first units' wheel adds 1, that of the next series adds 6; then the next time the former adds 1, the latter must add 7, and so on. This requires a very difficult combination of mechanical powers, continually increasing in intricacy as we go back from difference to difference until we come to the desired tabular number itself.

The difference engine was commenced for the British Government by Mr. Babbage in 1823. He had for some years devoted much thought to the subject, and had constructed for himself a small engine on the same plan, extending to two orders of differences. The expectations of the inventor were that the machine would cost £3,000 or £4,000 sterling. He was, however, a wonderful mechanist, probably the best in England, and kept continually devising new adjustments to avoid all possibility of derangement in the machinery from friction or otherwise, requiring everything, too, to be finished with an accuracy previously unattained in mechanism; so that the expense grew greater and greater beyond the anticipations of the Government, though only reaching a small fraction of the amount which it would save to the Government when completed, to say nothing of the gain in accuracy by all who use tables. It became very annoying to Mr. Babbage to go to the first Lord of the Treasury for grants of money which were made unwillingly and after much questioning.

The Government more than once asked the Royal Society to give an opinion about the matter; and after an investigation of the inventor's plans and an examination of the finished part of the engine by many of the most eminent men of science in England, the reply was invariably that there was no doubt that the engine could be constructed, and that it would be well worth the expense when completed.

In 1833 a difficulty with the engineer, owing to the dilatory manner in which the payments were made, caused the suspension of the work; and before the Government could or would make better arrangements, Mr. Babbage had so far progressed in his speculations on the subject as to have applied to calculating machinery the principle of the Jacquard loom, and planned a machine capable of performing any calculation or developing any formula that the human mind could conceive. He thought it his duty to communicate this fact to the Government, conceiving that it might induce them to discontinue the first and undertake the construction of the second engine, which, though much more efficient, was likely to be much less expensive than the former. The Government, or rather the successive Governments of England from 1833 to 1842, now and then discussed the matter, and at the latter date finally concluded not to go on with the work. Mr. Babbage had been continually for 9 years pressing for a decision on this point; and when it was arrived at, he at once dismissed the incomplete difference engine from his mind, and devoted his energies and his fortune to the perfection of his proposed analytical engine.

The difference engine had cost the Government about £17,000 and Mr. Babbage the best 10 years of his life. He received no compensation for his services, and asked none. For upwards of 20 years he employed in his own house and at his own expense, workmen of various kinds, to assist him in making experiments necessary for attaining a knowledge of every art that could possibly tend to the perfection of his inventions; and with the same object he frequently visited the manufactories of Great Britain and the Continent. He estimated the expense to himself at upwards of £20,000.

In the course of his labors on the new analytical engine, he built a forge and a foundery, extensive workshops, and a fireproof building for his drawings and

draughtsmen. The great difficulty consisted in the reduction of the *time* required for adding. Evidently, if all calculations were made on the bare principle, which we have explained, of turning a wheel 1-10th of a revolution for each unit added, the construction of a single important table would become the work of many years. We have only hinted at the complex nature of the machinery necessary to overcome this difficulty. Mr. Babbage now labored incessantly on it, each succeeding improvement advancing him a step or two. The intricate relations that soon arose among the various parts of the machinery became altogether beyond the power of the memory. He overcame that difficulty by devising a language of signs, a mechanical notation by means of which he succeeded in mastering trains of investigation "vaster," he says, "than the years ever allotted to one individual could otherwise have enabled him to control." These signs indicate briefly the shape of every part of a machine, the position of every part, the connection of every part with the others, the kind of each movement, the *extent* of each movement, the duration of each movement, and the actual space occupied by the various parts compared with the waste space about the machine. Thus it can be ascertained at a glance which motions are contemporaneous, and which successive, so that the same space may be occupied at different times by different parts of the mechanism. It can also be proved whether a given machine can or cannot exist, and if it can, whether it will or will not accomplish its desired object.

The analytical engine soon began to make serious inroads upon Mr. Babbage's fortune. He resolved, however, to pursue it to the extent of his ability. When he had fully explained the circumstances to his venerable mother, she replied: "My dear son, you have advanced far in the accomplishment of a great object, which is worthy of your ambition; you are capable of completing it; my advice is, pursue it, even if it should oblige you to live on bread and cheese." Thus encouraged, he went to work with redoubled energy. The undertaking was more stupendous than he supposed; or, rather, his inventive genius led him to continually add improvements which involved time and labor. In 1864 he wrote: "If I survive some few years longer, the analytical engine will exist, and its works will afterwards be spread over the world." We do not suppose that he left it completed at his death. We only hope that he left it sufficiently advanced to enable and induce others to complete it. The plan in its details was sufficiently perfected in 1852 to show to the Royal Society, whose committee reported that there could be no doubt of its feasibility and effectiveness.

Mr. Babbage published several works of great importance, the best known of which is the "Economy of Manufactures and Machinery." A more thoughtful book, and one better calculated to arouse thought, can scarcely be found; and though first published over 40 years ago, it has lost none of its value at the present day. He also wrote a lucid yet profound book which he called "The Ninth Bridgewater Treatise," being a discussion of the bearings of mathematics on religion. One of its most striking features was a mathematical demonstration that no matter what amount of experience rendered a miracle unlikely, the independent testimony of a comparatively small number of reliable witnesses was enough to establish its credibility. We think that he did not make sufficient allowance for the liability of an honest witness to be deceived, or to misinterpret what he saw; but he must be said to have conclusively answered all who hold that a miracle is an impossibility. "A miracle," says he, "has nothing in its nature inconsistent with our belief of the uniformity of nature. All that we see in a miracle is an effect which is new to our observation, and whose cause is concealed. Its credibility depends on the nature of the evidence by which it is supported." He curiously illustrated the truth that events of the most unexpected and unusual kind might yet happen according to a known and foreseen law, by an experiment with his difference engine. Taking some friends once to see the engine, he set it to count the series of natural numbers, 1, 2, 3, 4, 5, 6, etc. After continuing the series for a while, he pointed out the fact that it was impossible for the machine thus set, from its very structure, to do otherwise than count these numbers, increasing by one each time, as far as 100,000,000. To save time, he then set it ahead nearly to that point, and bade

them mark the result. The numbers were shown as follows :

99,999,997,
99,999,998,
99,999,999,
100,000,000,
100,000,001, (after this the law
100,010,002, changes)
100,030,003,
100,060,004,
100,100,005,
100,150,006, etc.

The machine obeyed a new law after the 100,000,001st term, adding 10,000 times the series known as triangular numbers to the continuation of the original series. He then showed that this law would govern 2,761 terms, when a new law would come into operation ; that this new law would last for about 1,430 terms, and then be succeeded by another; and so on *ad infinitum*. The machine could be set so that any of these laws would exist for any assigned number of times, and any of them might cease and reappear after any desired interval. Now, if a person knowing nothing about this engine could watch it count the natural numbers up to 100,000,001, his expectation that the next number shown would be 100,000,002 would no doubt be so strong as to amount to a feeling of certainty. Yet this expectation would be disappointed without any violation of natural law, but in such strict conformity thereto as to be foreseen by any one understanding the mechanism. So, argued Mr. Babbage, what we call a miracle may seem strange and unlikely to us only because of our ignorance, though known to the Creator of the universe to be a necessary consequence of the manner in which he has made his works. We may add that this view of miracles has been adopted by all the principal religious writers on the subject since the publication of Mr. Babbage's work.

With Mr. Babbage's minor labors, his recreations, and the "chips from his workshop," a volume might easily be filled. While yet at college, he joined with Herschel, Peacock, and others, in introducing the differential notation of Leibnitz into England in place of the less manageable fluxions of Newton. He was skilled in finding the key to writing in cipher, and, to aid him in such pastime, went to the trouble of classifying all the words in the English language, according to their lengths, the repetitions of the same letter in them, and the positions of the letters so repeated. He was fond of making automata of various sorts ; for instance, to play games, the principal being that, at any given state of the game, the mechanism must make a certain move. His name is indissolubly associated in England with the broad-gauge railway, the final adoption of which was due to an elaborate series of experiments which occupied his spare time for several years, and a luminous report, in which he summed up the results of his investigations. Improvements in storm signals, in mechanism to make it difficult to counterfeit bank notes, and in the English postal system, are also due to him. His foible was a hatred of organ-grinders and other street noises. He was continually waging war with them, but the only result was to make them more and more desirous of annoying him. A much better course would have been to acquire the habit of concentrating his mind on his work so as not to be disturbed by such noises.

In conclusion, to throw some light on the workings of an inventor's mind, we will quote a remark which he made a few years ago :

"I think one of my most important guiding principles has been this—that every moment of my waking hours has always been occupied by *some train of inquiry*. The necessary training was difficult. Whenever at night I found myself sleepless, and wished to sleep, I took a subject for examination that required little mental effort, and which also had little influence on worldly affairs by its success or failure. On the other hand, when I wanted to concentrate my whole mind upon an important subject, I studied during the day all the minor accessories, and after 2 o'clock in the morning I found that repose which the nuisances of the London streets only allow from that hour until 6 o'clock in the morning."

The St. Petersburg War Office states, in an official order, that the number of breech-loaders required for the entire army on a war footing has been completed at last, and that there is also an ample supply of cartridges on hand. The rifle adopted is an improved needle-gun, called, after the manufacturer, the Krick pattern.

REMARKS ON CONCRETE BUILDING.*

By A. W. BLOMFIELD, M.A., F.R.I.B.A.

From the "English Mechanic."

In the few remarks which I have to make on this subject, I shall confine myself to the consideration of that system to which walls are constructed *in situ*, by filling concrete into cases, or moulds, made to shift to the various requisite heights and positions as the work proceeds. The system of building with blocks of concrete or artificial stone, cast separately and put together when dry, having little to distinguish it from the ordinary methods of construction, calls for no special notice.

Much misconception, now happily disappearing, was excited as to the pretensions of concrete building, and, in consequence, many absurd objections have been raised against it. As one instance among many, I may mention that, when a few years ago a paper was read on the subject at a meeting of the Architectural Association, an architect gravely objected that, though much had been said about concrete walls, nothing had been said about roofs. He considered that a building was useless without a roof, and he wanted to know how it was proposed to roof a concrete building. There seemed, in fact, to be an idea that the advocates of concrete looked upon it as a new invention destined to supersede all other methods of construction. Any one who has taken the smallest trouble to investigate the subject is, of course, aware that, like many other so-called inventions, it is merely the revival of a very old expedient, though some of the features of the machinery now generally employed are certainly new, and very ingenious, and useful. The authors of other papers will, no doubt, enter more minutely, and with more scientific details than I can, into the question of the materials and proportions proper for concrete building; I shall, therefore, say little on this point. For the same reason, coupled with a desire to be brief, I forbear to mention the numerous tests to which the material has been subjected, and the proofs of extraordinary strength and durability which have been the result. One significant fact, however, should be noticed. In using ordinary materials, no sooner is a building completed than decay commences at once, in a greater or less degree. Portland cement concrete, on the other hand, has been proved to continue to harden for a very considerable time—some say even as long as two years. As far as I can ascertain, the only cementing material to be relied on is Portland cement of the best quality, and for the other ingredients, any may be used that are usually employed in carefully composed concrete for ordinary purposes, especial care being taken that they be quite clean and free from clay or earthy particles. The proportions vary from 1 of cement, and 8, 9, or even 10 of other material for walling, to 1 of cement, and 5 or 4 of other material for lintels, steps, and flats for landings. The interior of walls of more than 4 in. in thickness may be packed with rough stone, broken bricks, chalk, or any other similar material that can be easily procured in the neighborhood.

Time will not allow me to enter into any description of the different sorts of cases and machinery now in use, and the various details, manipulation, and use of the material; but so much has been said and written on the subject, and the system has now become so common, that anything of the sort would probably be unnecessary.

The chief advantages of concrete building may be summed up in a few words: First, cheapness; secondly, strength and durability; thirdly, rapidity of construction; fourthly, economy of space.

The chief drawbacks appear to be: First, its liability to failure, from the use of improper materials, or from the want of knowledge and proper care, or from the wilful misuse of good materials; secondly, the limits which the material and method of construction impose on architectural design and decoration.

The question of cheapness depends on locality. As a rule it will be found that where bricks are the local material, concrete will be, bulk for bulk, cheaper; and, as it may be used thinner than brick with

* From the Report of the General Conference of Architects, 1871.

equal strength, and without the employment of skilled labor (except that of a foreman), the saving is usually considerable over brickwork. On the other hand, where a local stone may be obtained very cheaply, concrete will not be found to effect any saving in ordinary walling.

In respect of strength and durability, my experience has led me to put the greatest possible faith in carefully compounded Portland cement concrete. I do not think that its capabilities in the way of fire-proof flooring, without any adventitious aid of iron girders or other supports over considerable areas, has ever yet been properly tested. Its extraordinary strength when employed for walls must now be fully recognized by all who have given it a trial.

With regard to the next point, rapidity of construction, although no doubt many concrete buildings have been run up in an incredibly short space of time, I think that too much stress has been laid on this as an advantage, and I believe that some disasters which have occurred are attributable (in part at least) to undue haste. I have myself seen partial failures from this cause, which, by the subsequent hardening of the concrete, have stopped and gone no further.

Economy of space is only gained by the possibility of making walls (particularly internal division walls) thinner than in ordinary brickwork. Though this seems a small matter, it will be found that in a large establishment, with many small divisions, the saving in space covered is considerable. I now come to the drawbacks. Of these, the first speaks for itself. It is, no doubt, the most serious objection to the system, and has deterred many from giving it a fair trial. I pass it by, however, as a point which occurs to every one, in order to conclude with a few remarks on the limits imposed by this material and method of construction on architectural design and decoration.

It is, of course, possible to build plain walling in concrete, using quoins, window dressings, strings, cornices, etc., of stone; but I refer to cases in which, from economical or other motives, an architect may desire to confine nimself entirely to the use of concrete, without brick or stone. In connection with this view of the subject, I take the first opportunity of protesting against the idea of a concrete arch. Concrete is in fact a solid mass of artificial stone, and it would be as rational to scoop out the underside of a York landing or a Portland stone lintel into an arched form to increase its strength, as to mould a mass of concrete into such a shape with the same object. Concrete construction such as I have described is essentially monolithic, and the arch has no proper place in it, except perhaps as a mere decorative feature, evidently unconnected with the construction, if, indeed, such a use does not carry its own condemnation. In saying this, I do not of course refer to barrel vaults and domes which may properly be constructed as solid crusts or shells in concrete.

Wherever any architectural character or decoration has hitherto been attempted in concrete building, it has taken the form of the usual imitations of stone in Portland cement, and this has had the effect of increasing the prejudice against it as an encourager of stucco and shams. Now, Portland cement stucco, so far from being necessarily a sham, seems to me to be an admirable and useful material, which through long abuse has fallen into disrepute, but which is capable of perfectly legitimate treatment with very good results. We must not, of course, look for effects of light and shade produced by bold projections of cornices or string-courses, not for sculptured decoration; but we may get color and surface ornamentation, as, for instance, by incised, stamped, or "sgrafito" work, without the use of any other materials than concrete and cements. This is what we ought to aim at, and whatever is done, the monolithic character of the structure should be borne in mind, and nothing should be allowed to twist it into forms and appearances foreign to its nature, merely to make it look like other buildings.

For suggestions as to legitimate and artistic treatment of external plaster-work we have plenty of examples, not only abroad, but in numerous old houses in all parts of our country. Ornamentation of this kind could scarcely be so expensive as the elaborate cast imitations of stone which are usually employed.

I think, however, that in this system of building, a great deal may be done without plastering the surface, by using a fine concrete which may be kept to the external face of the work, and left untouched

when the cases are removed. It is true that it is impossible, for several reasons, to avoid showing the marks of the different levels at which the cases are fixed, but this, being a necessity of the method, should be made a feature; the marks should be clearly defined, and advantage might be taken of them to vary the color and composition of the surface concrete. Finally, broken granite or quartz, fine sea-shingle, and colored sands may be suggested as materials for it.

In conclusion, without claiming for concrete building the extraordinary merits which it has been supposed to possess, I think it is a subject well worthy of the attention of architects, and one which is capable of very great development, particularly in an artistic point of view, but in this direction nothing can be done so long as the only aim is to show how well it can be made to imitate some other material and some other method of construction.

THE DESICCATION OF WOOD.

By M. A. PAYEN.

Translated Abstract from "Annales de Conservatoire."

The methods heretofore employed in the desiccation of wood may be referred to one of the following classes :

1st. Coatings applied to the surface of wood in order to prevent the contact of air and moisture.

2d. Simple immersion in an antiseptic fluid.

3d. Vital suction or filtration, of which the Boucherie process is the type.

4th. Injection of antiseptic fluids. in a closed vessel, by alternation of vacuum and pressure.

5th. Artificial desiccation followed by injection in closed vessels.

In this article we propose to describe the different processes of desiccation by means of drying ovens. It is these ovens, that we would particularly examine ; considering their mode of construction, their action, and advantages in their application either to simple desiccation or to preliminary drying to be followed by injection.

The presence of water and air in wood, is one of the principal causes of the fermentation of its organic matter and of its consequent alteration and destruction. These changes often remove an appreciable part of organic matter containing combustible carbon and hydrogen. Again the hygroscopic water contained in the wood, in its volatilization absorbs a part of the heat developed in combustion, and thus diminishes its calorific powers.

In order to give a precise notion of the utility of the desiccation of wood-fuel, we should compare the quantity of useful heat obtained from dried and from green wood. This comparison is easily made by taking for standard the mean elementary composition of some wood, say oak, and the equivalent of carbon given under the two conditions.

100 parts of dry oak contain 50 of carbon, 6.20 of hydrogen, and 43.80 of oxygen. To the calorific power of the carbon (50) should be added, the equivalent representing the excess of hydrogen (somewhat variable in different kinds of wood) above the quantity necessary to unite with the oxygen so as to form water. In oak this excess is 0.630 ; equivalent to at least 1.89 of carbon. We may therefore consider 100 parts of dry oak as equivalent to $50 + 1.89 = 51.89$ of pure carbon.

But in order to determine the quantity of useful heat, it is proper to deduce that which, in the process of combustion, transforms into vapor the hydrogen and oxygen. This water of composition is $\frac{50}{100}$ of the total weight, absorbing in transformation into vapor at the temperature of combustion a quantity of heat equivalent to 5 of carbon, which is to be deducted from 51.89 ; giving a remainder of 46.89 of useful carbon, which represents the calorific power of 100 parts of dry oak.

Now suppose that moist oak contains 45 per cent. of water : As 100 parts desiccated wood represent 46.89 of carbon, 55 would give 25.79 of carbon ; from which is to be deducted 4.50 used in vaporizing the 45 parts of water ; giving 21.29. It follows that 225 parts of green wood must be burned to give as much

useful heat as 100 of dry. But besides this loss, it happens that in certain cases, as in the melting of glass and of zinc, it is impossible to attain the desired end by use of green wood. Hence, desiccation, almost always useful, becomes an absolute necessity in the manufacture of glass and in metallurgy.

In the injection of wood under pressure the elimination of the water of moisture permits the antiseptic liquid to take its place. Hence the more or less complete expulsion of the water would be useful in various ways, and would fulfil one of the conditions most favorable to its conservation.

There are two methods of desiccation: the natural, by long exposure to air, under sheds; and the artificial, by means of stoves or ovens. The natural process is insufficient for preservation. For however great the pains and long the exposure, there always remains a residuum of water, amounting to from 10 to 20 per cent.; which is sufficient to cause fermentation, to invite insects, and to favor cryptogramic growths. This sort of drying is suited only to wood for carpentry or furniture; being sufficient to prevent change of dimensions or warping when it is removed from farther action of humidity. The artificial process better assures preservation, since it can drive from the wood all the contained moisture; still this condition cannot be maintained against the influence of the atmosphere, except by some coating impervious to moisture.

On the other hand, the preparation of the wood, or its injection with antiseptic fluids by the method of close vessels (*en vase clos*) cannot be successful unless the wood has been sufficiently dried, so as to allow the withdrawal of the air from the tissues. If moist wood is subjected to this process, the liquids cannot escape; and of course their place cannot be taken by antiseptic fluids.

Experience has shown that injection *en vase clos*, is practicable only upon woods sufficiently dried, and this explains the invention of so many apparatuses of desiccation. The use of these has progressed but slowly; a fact due to their imperfection. Either the price of construction was too high, or the time necessary for desiccation was too protracted. Only within a few years has this preliminary desiccation become successful; a success due to the new apparatus to be described further on in this article.

Until these inventions were made it was necessary to leave wood (especially railroad ties) exposed to free air for 4 to 8 months before it could be worked up. This was onerous; for besides loss of interest on stock, there was expense of shedding and of transport.

Attempts to desiccate wood date from time long back. Wollaston and Fourcroy recommended the process; and Newmann employed steam for the purpose. Placing the wood in a large wooden box, he admitted steam from a boiler and drew off the condensed vapor charged with albumen and sap. The progress was tested by the color of the liquid drawn off. When this became colorless the wood was taken out. This method would have given favorable results if superheated steam had beem employed so as thoroughly to permeate the wood; but the expense would have been too great.

In 1837 M. de Mecquenem invented a process which consisted in subjecting the wood to a current of heated air in a closed vessel; the current being impelled by a blower. The air entered at the bottom and escaped at the top.

In 1839 M. Charpentier patented an invention in which he made use of a hermetically closed chamber, in which the wood was exposed to the action of air heated by passing over metallic plates, and introduced through 4 longitudinal tubes disposed upon the floor of the furnace, from which it was discharged into the heating chamber. The vapors and the moist air escaped by 4 longitudinal pipes placed in the upper part of the furnace and communicating with the chimney.

In 1848–1853 Bethell, who, as is well known, gave much attention to the preservation of wood and vegetable substances, took out a number of patents in England and France. One of these consisted of a rectangular brick chamber, with hollow walls filled with cinders to prevent radiation; the arched roof being constructed in the same way. One end was left free to admit a carriage on rails. A double iron door closed this entrance when the chamber was filled. At the other end was a furnace provided with a grate for the burning of coke, oil, wood, or tar, according to the end in

view whether simple desiccation, or *smoking;* that is, impregnating with antiseptic gases proceeding from the incomplete combustion of tarry substances. The products of combustion passed through a central flue at the bottom, which biforcated near the entrance; the branches carried the smoke to the bottom of the chamber, from which it passed over the wood. The smoke and gases and moisture escaped at one end by a pipe at the top, and at the other by a sort of ventilating chimney. Bethell says the temperature should be kept at about 110 deg. Fahr. The time varied from 8 to 12 hours. This rapidity must have been at considerable expense of fuel. The rapid movement of the heated gases did not permit the complete utilization of their caloric, and it is doubtful whether large pieces of wood, as railway ties, can be thoroughly desiccated in so short a time. This indeed was shown by numerous experiments made at London in 1853 by the "Desiccating Company." The wood was placed in a close chamber of a capacity of about 1,000 cubic metres. The air was heated in Taylor's apparatus, as in the metallurgy of iron, and was driven over the wood by a ventilator; but slowly, and in such a quantity that the atmosphere of the chamber was entirely changed in 3 or 4 min. Nearly 9 hectolitres of coal was consumed in 24 hours. It was found that an average of 15 days was required for complete desiccation at a temperature of from 45 deg. to 60 deg. This low temperature and protracted time seem to be better for woods that are to be used in carpentry, cabinet work, and the like.

The furnace of M. Guibert of Tourlaville, invented in 1861, was in essential points similar to that of Bethell, patented in England in 1848.

Reuther's invention (1860) is intended for the desiccation of ties and their injection with creosote. The products of combustion are introduced by means of canals at the bottom of either side of the chamber. These are covered with iron plates which heat the air within the chamber. At the extremities near the door, are two vertical pipes which enter the hollow space in the walls and the vault. Two chimneys surmount the vault at either end.

Before the wood is put in, the two orifices at the end of the canals is opened so that the smoke and heated gas may enter the chamber and raise its temperature. At the beginning of the operation, one chimney is closed so that the products of combustion may pass directly to the other chimney by the vertical pipes. When the vault is warm enough, the second chimney, that near the entrance, is closed. The time of desiccation is 24 hours; the temperature is gradually raised to 100 deg. If the time for any reason is shorter (as 12 hours), still the temperature is constantly maintained at 100 deg. But this is not approved, as carbonization is likely to ensue.

In all the apparatus described, the gas, smoke, and heat are introduced at the bottom, while the discharge is from the top. This disposition is defective, because the heated air rises directly to the top of the chamber and escapes without having had time to become saturated with the moisture of the wood.

Peclet in his "Traité de la Chaleur," tome ii., chap. vi., noticed this defect, and recommends a reversal of disposition. He states that in 1822 M. Ternaux effected this in a vermicelli desiccator at Saint Ouen, and that the operation was much more rapid. He says: "We thus find a condition of great importance; that the issue of vapors should always be effected at the bottom of the drying-chamber. This prevents stagnation, and is at the same time very favorable to the saturation of the heated air; for hot air moves rapidly while rising in a denser medium, but moves slowly and distributes itself uniformly when it circulates downward."

Peclet proposed the following process for drying wood and peat: Two parallel galleries with a furnace at the bottom of each, and horizontal pipes under the bottom, through which the smoke is to pass uniformly and in succession, and so as to distribute the heat as uniformly as possible. Each gallery is to be closed at both ends by double doors, and is to be provided with rails for iron wagons, upon which the wood is to be piled so as nearly to fill the chamber. The smoke of the two furnaces passes into a common chimney of large section, having a draft-regulator at its top. The adjacent walls of the galleries form a closed space; in the middle of this is a chimney which communicates below with each of the galleries by means

of orifices provided with registers. On each side of the chimney, at the bottom, are the furnaces.

This process was applied some years after at Graffensladen. The apparatus was of trapezoidal form; there were 6 chambers heated by 7 furnaces; disposed in 2 sections separated by a passage. The vapors escaped by lateral orifices at the bottom, opening into the chimneys. Each furnace was connected with a horizontal brick chamber, hermetically closed at the end, which divided and returned upon itself to open into vertical chimney near the furnace. The desiccation lasted night and day for from 10 to 20 days. Experience fixed the temperature for oak at 40 deg. and for pine at 50 deg. The action of this apparatus is very slow, and therefore not fitted for desiccation of railroad ties.

In 1851 M. Imbert took out a patent for an oven for drying wood intended as fuel, in metal or glass works. The chamber was long and its bottom was covered with metallic plates forming three longitudinal tubes which terminated at one end in the chimney of a small furnace set several metres below, in a vault. The carriages entered at one end and were removed at the other, near which the products from the fire entered by orifices in the plates. The gases escaped by an orifice in the lower part of the oven. When the wood on the carriage nearest the discharging door was dry enough, it was shoved out by another introduced at the entrance. The temperature was lower nearer the entrance, so that the wood advanced in a contrary direction to that of the motion of the gases, and passed into successively higher temperatures.

This device of making the wood advance in a direction contrary to the motion of the heated gas was afterwards recommended by Lechatelier in 1853, before the Society of Engineers. He proposed, for desiccation of ties which were to be injected, an apparatus like the kiln employed in annealing glass. The wood was to be put in a long gallery, on wagons, and to be slowly moved in a direction contrary to that of the heated gas, towards the maximum point of temperature. The introduction and removal were to be as in the last case. M. Lechatelier thought that this operation could be conducted with the greatest facility; and that with a kiln 100×2 metres, 500 *steres* could be desiccated in 24 hours.

In 1863 M. Blythe, an English manufacturer, who was engaged at Bordeaux and Landes in the injection of wood with sulphate of copper, invented the apparatus which has now come into most general use. This is a double oven, composed of two rectangular chambers of clear dimensions 3.25 m. wide, 2.50 high, 3.25 long. The outer and partition walls are of brick, resting on a foundation of masonry. Two brick vaults roof the chambers. The side and partition walls are hollow, the space being 7 to 8 centm. wide, and extending the entire length and height of the wall. These hollow spaces communicate with the lower part of the chambers by small openings, and with small chimneys at the top. At either end of each chamber is a double gate of iron, or wood covered with galvanized iron. In each chamber, at a little distance from the side walls, are set two walls of masonry for the rails. Between and below these walls is a long arched passage, communicating with a furnace. The furnaces are covered by a fire-brick vault, which projects over the fire-grate far enough into the chamber to cover the flame. Along the whole length of the walls of the passage just described, and inside the rails, run two small flues or passages; and between these is another flue, so connected with the furnaces as to form a separate passage for each, so as to prevent the mixture of the products of combustion.

The action of the apparatus is as follows: Four wagons of wood are introduced, and the doors are shut. The products of combustion enter the passages, from the furnaces; thence they enter through orifices into the two flues just inside the rails. The heated gases now rise and pass through the wood, taking up the water that has been converted into vapor. In doing this they cool, and then pass along the walls, which are colder than the middle of the chambers. Arriving at the bottom, they escape by orifices regularly distributed into the hollow wall, and pass out the chimneys. By this method a constant and uniform circulation is assured, and the temperature is sensibly uniform.

The construction of an oven like the one just decribed, costs about 8,000 francs, and the expense for each tie, including

fuel, labor, handling and interest on capital, is 0.07 fr.

M. Blythe afterwards modified his apparatus in some of its details; not affecting the general action. As the iron plates of the flues in the original oven were rapidly destroyed, he substituted hollow fire-brick.

In France 11 of Blythe's apparatus have been erected, 9 of which are still in operation.

Artificial desiccation, to be efficacious, should remove from the wood a volume of about 300 litres to the cubic metre, so as to allow the injection of an equal volume of creosote, or of a solution of sulphate of copper, at 0.02; equivalent to 6 kilogs. of crystallized; these proportions having been found sufficient for preservation. An obvious advantage of this method of desiccation is that the process can be completed within 24 hours after a tree has been cut down, and that water-logged timber can be subjected to it.

PAPER-MAKING IN JAPAN.

From the "Journal of the Society of Arts."

The art of paper-making in the country of the Mikado forms the subject of a very interesting Parliamentary document just issued, comprising reports from three of her Majesty's consuls in Japan. Mr. Lowder's report, addressed to Sir H. Parkes, from Kanagawa, was accompanied by numerous colored illustrations, the work of native artists, and costing only $1. These illustrations now accompany the report in the form of engravings, and are highly interesting, being singularly bold and graphic, conveying a very clear idea of the processes referred to.

According to Mr. Lowder, the manufacture of paper from the paper-mulberry (*Broufsonetia papyrifera*) was introduced into Japan about A. D. 610, being mainly brought about by the skill and enterprise of Shôtokn Taishi, a son of the reigning Mikado, who improved on what he had previously learned from Donchô, a priest from the Corea. This Donchô is said to have been a clever man, learned in the Chinese classics, and a skilful artist. But his paper was not all that could be desired. It did not take ink well, and it tore very easily. Taishi had recourse to the paper-mulberry, and caused it to be extensively planted all over the country, taking measures at the same time to have the mode of manufacture largely promulgated among the people. From the year 280, paper had been imported into Japan from the Corea, but soon after 610, thanks to the ingenuity of Taishi, the Japanese learned to make their own paper, and even made it of better quality than that of Corea. The art, as practised in the present day, is very rude in its appliances, but is very satisfactory in its results. The mulberry stalks, cut into lengths of 3 ft., or rather less, are steamed, and the skin thus softened is afterwards stripped off by hand. The skins thus peeled off are hung up to dry, a process which occupies from 1 to 3 days. They are tied up in bundles, and exposed to the action of running water for 12 hours, or perhaps 24. After this washing, the outer dark skin is stripped off from the inner fibre by means of a knife, the tool being held stationary with the right hand pressing on the material, which lies on a straw padding. The operator then draws the material towards him with the left hand, and as the stuff passes under the edge of the knife the outer fibre is stripped off. The dark outside skin is used for making inferior kinds of paper. After being thoroughly washed in running water, which causes it to open out flat, it is boiled. It is then allowed to rot, and is well beaten, after which paper is made of it, by admixture with the "tororo." In years when the paper-mulberry is scarce, this kind of paper is sometimes made of the common mulberry. The mode of manufacture is the same, and the leaves are occasionally made use of for the purpose.

Reverting to the treatment of the inner fibre, we observe that this is parcelled into lots of about 32 lbs. avoirdupois each. It usually takes 3 days to make this into paper, but adepts can accomplish its manufacture in 2. These parcels are taken to the river and thoroughly washed, after which they are steeped in buckets of water. The water is then run off, and heavy stones are placed upon the fibre to squeeze out

the remaining liquid. The parcels are next boiled, so as to get rid of all sticky and glutinous matter, and the fibre is then called "sosori." Great care has to be taken that the boiling goes on evenly, and sometimes the boiling has to be assisted by throwing in wax-ash or common lime; but the admixture of either of these will slightly affect the color of the paper. The boiling, moreover, is not carried on by means of common water, but by the use of water in which the ashes of burnt buckwheat husks have been infused. After this boiling, the sosori undergoes a second washing, in order that the residue of the ash infusion may be thoroughly expelled. For this purpose it is placed in a basket, through which running water is allowed to percolate, after which the basket is lifted up, and the water runs off. The night before the paper is made the sosori is again washed, and the next morning it is pounded "for about as long a time as it takes to boil the rice for breakfast." When paper is made in the winter a little "tororo" is mixed with the sosori before pounding, but in spring rice-paste is used The tororo is a plant, having a root about the same size as that of the common dock. The sprouts and skin of the root are scraped off, and the root is then beaten. When required for use the "tororo" roots are boiled into a tolerably thin paste, and strained through a fine hair sieve into a tub.

In making the paper called "hanshi," the sosori is first formed into a large ball, from which lumps are broken off as required. These lumps are cast into what is called a "boat," and thoroughly mixed with well-strained tororo paste. The necessary pulpy mass is thus formed. In making "hanshi," the boat containing the pulpy material has a length of 6 ft. and a breadth of 3. A sort of tray or frame, of the requisite size, has a false bottom of plaited bamboo. This tray is dipped into the pulp, or the pulp may be poured into it. An inner frame is then fitted so as to press down on the false bottom and keep it tightly in its place. A peculiar and dexterous jerk is then given to the apparatus, which has the effect of "setting" the paper. The frame is then placed in a leaning position against an upright rest in the boat to allow the water to run off while another frame is prepared. By the time a second frame is ready, the first may be removed, and the entire manipulation is such as can be performed very quickly by experts in the manufacture. Paper made in the winter with "tororo" has the advantage over that made in the spring with rice paste, that it is not likely to become worm-eaten.

In order to dry the paper, the sheet is removed from the frame with a piece of bamboo, the thicker end of the paper being dexterously curled round the stick. By means of a brush the paper is laid on the drying-board face downward. Five sheets are placed on each side of the board, which is 6 ft. long, and each manipulator requires 40 drying-boards. In fine weather the paper drys quickly, in wet weather it is sometimes dried by the heat of a fire. Cutting is effected by a knife, applied to parcels of 100 sheets. Packing into bundles for market follows.

Mr. Annesley, writing from Nagasaki, describes the mode of making paper from the bark of the "kaji" tree, and says:—"There are no reasons why the 'kaji' tree should not flourish in England, more especially if planted in a damp soil; and when it is considered that paper could no doubt be manufactured from this bark at a cheaper rate than it could be made from rags, added to the considerable strength it can attain, and the various useful purposes to which it can be applied, the cultivation of the kaji shrub in England is well worthy of a trial." The writer adds —"Some inquiry after this bark has been made by home paper manufacturers from merchants at this port, and samples have been sent to England, where its value will no doubt be appreciated and turned to account." The many forms which paper takes in Japan seems to suggest that we are far behind in the development of this industry. The Japanese will make paper "warranted to wash." They also manufacture oil-paper for rain-coats and other purposes. Some of the common paper is made so tough that it can be torn only with difficulty. Paper is made to have the weight and hardness of heavy wood, or the lightness and elegance of net. Paper hats are made in imitation of straw, the paper being twisted, plaited, shaped, and varnished. Leather is also imitated, and these imitations have excellent qualities to recommend them. Coats, shoes, umbrellas, pocket-handkerchiels, and numberless other articles are made from paper. As

for the raw material, we are told that the Japanese are acquainted with the method of manufacturing paper from rags, but never adopt it, preferring to make their paper from the bark of trees. If the kaji tree can be successfully grown in England, our own paper-makers might find it a very-useful source for a portion of their raw material. The Japanese seem to luxuriate in an abundance of "sosori;" but in this country the paper-making industry is hemmed in by a comparatively narrow circle.

This news comes from Japan very opportunely, and the document before us states that sundry samples of the material have been sent to the South Kensington Museum. The subject is not merely curious, but important. Sir H. Parkes regrets that the information afforded in the consular reports is not more complete, but says :—"It has not been found easy to obtain information from Japanese informants engaged in the trade relative to the production of the raw material or the mode of manipulation." The manufacture appears to be carried on in the interior provinces, and no opportunity of observing the process has been met with at Yeddo.

MODERN CANNON POWDER.

From "The Quarterly Journal of Science."

In the year 1799, nearly a century ago, General Sir William (then Captain) Congreve was sent to Plymouth to examine the gunpowder with which the Fleet was then supplied, on which occasion he reported that there were only 4 barrels of serviceable powder in the whole of His Majesty's ships. This state of affairs was no doubt due to the fact that the country was then entirely dependent on private manufacturers for its supply of powder, and that the proof to which it was subjected was not such as to insure its being of good quality. On discovery of the gross frauds which were thus being carried on with impunity, the Government Gunpowder Factory at Waltham Abbey was established, and, under the able superintendence of Sir W. Congreve, the quality of the powder supplied to the army and navy was greatly improved.

From this date until the general introduction of rifled guns in 1860, very little progress was made towards the development of this important manufacture, the only changes being in the direction of improvements in the preparation and purification of the ingredients, the quality of the finished powder being thereby improved, while its character remained unaltered. During the whole of this period the description of powder used with all cannon, was what is technically called "L. G.," or "Large Grain," in contradistinction to "F. G.," or "Fine Grain," which was used with small arms and muskets; but this powder was believed to be too violent for use in the rifled breech-loading guns introduced about 12 years ago, and a modified kind was therefore adopted, on the recommendation of Sir William Armstrong. The modification consisted in making the powder much larger* in the grain, and, in addition, coating it with a thin film of graphite, so as further to retard its combustion, and thus to reduce the strain upon the breech-closing mechanism of the gun.

This new powder was at first called "A_4," but its name was afterwards changed to "R.L.G.," or "Rifle Large Grain" powder, when its use was extended to both muzzle-loading and breech-loading rifled guns. Now, at the time of the introduction of this modified powder, the means of testing the action of the charge in the bore of a gun were very imperfect, and the change then made was founded almost entirely upon theoretical considerations. In order to understand these, and also the results of more modern experiments, it will be necessary to say a few words on the subject of the combustion of gunpowder.

In the first place, it must be borne in mind that gunpowder, unlike nitro-glycerine, fulminate of mercury, and other detonating substances, is not a chemical compound, but only a mechanical mixture. By the incorporating process during

* The size of grain in "L.G." powder is such, that it will pass through a sieve of 8 meshes to the inch, and be retained on one with 16 meshes, while the limits of "R.L.G." or "A_4" powder are between a 4-mesh and an 8-mesh sieve.

manufacture, the three substances of which powder is composed—saltpetre, sulphur, and charcoal—are so intimately mingled that the eye cannot detect the presence of any one of them in a free state. They are, notwithstanding, only mixed, and the saltpetre can be readily dissolved out by water, or the sulphur sublimed, in the form of vapor, by the application of a moderate heat, leaving in either case the other two ingredients chemically unchanged. The more intimate the mixture, the more nearly does gunpowder approach to a chemical compound, and the more violent is its combustion; but there always must remain a vast difference between the most complete mechanical mixture and the most unstable chemical compound.

For this reason, the combustion of gunpowder is only very rapidly progressive, and not instantaneous, as is the case with the violent explosives mentioned above. It is this difference that renders gunpowder so valuable as a propelling agent, for, were it not for its comparatively mild action, no gun could be made sufficiently strong to resist its force. The material of the cannon would be broken before the inertia of the shot could be overcome.

Now, supposing one grain or particle alone to be ignited, it will be first inflamed over its whole surface, and the progressive combustion will take place from the exterior to the interior. Its *rate of combustion* will therefore depend upon both its shape and size, leaving out entirely for the present the question of density and hardness. A particle of spherical or cubical form will expose less surface to ignition, in proportion to its volume, than one of an elongated or flat shape, and will consequently require a longer period for the combustion of its entire mass; the larger the particle also, the longer will be the time required for its consumption. Looking, then, at one grain of powder by itself, we may safely say that the larger it is, and the more nearly does its form approach to that of a sphere, the longer will its combustion take, and the slower will be the evolution of the gas. When, however, we come to regard the action of an aggregation of such particles, as in the charge of a gun, the *rate of ignition* of the whole charge is also affected by the size and shape of the grains. The part of the charge first ignited is that near the vent, or touch-hole, and the remainder is inflamed by contact with the heated gas generated by the combustion of this portion, so that the rate of ignition of the whole mass will be regulated by the greater or less facility with which the gas can penetrate throughout the charge, which is itself dependent upon the size and shape of the interstices between the grains. If the grains be spherical and regular in form, the interstices will be comparatively large and uniform, and the gas will penetrate the mass with facility; again, the larger the grains, the larger the interstices between them. If, on the other hand, they be fat or flaky and irregular in shape, the passage of the gas will be more difficult, and the rate of inflammation of the charge reduced.

We see, therefore, that the considerations which affect the more or less rapid combustion of an individual grain of gunpowder also affect the rate of ignition of a charge of such grains, but in an opposite direction; so that a form of grain which will individually burn rapidly may offer an increased resistance to the passage of the heated gas through the charge, and thereby retard its ignition, while a grain which will burn more slowly may allow of the charge being more rapidly ignited. By varying the size and shape of the grain alone, a powder may therefore be obtained a charge of which shall be ignited rapidly throughout but burn comparatively slowly, or one which shall be ignited more slowly, but when once inflamed burn very rapidly. It is necessary to draw a clear distinction between a rapidly igniting and a quickly burning powder; this difference will be more apparent when we come to the discussion of more modern powders.

The grains in both L.G. and R.L.G. powder are very irregular in shape, and the latter is double the size of the former, so that the individual grains will burn more slowly. It was, therefore, believed on theoretical grounds that the larger powder would exert a less violent strain upon a gun, and it was adopted, as we have said, for our rifled guns, the question of *density* being regarded at that time as of minor importance, though it was already attracting some attention. It has since been conclusively proved by experiments that the *density* and *hardness* of the grains of powder are of quite as vital im-

portance as their size and form, in determining the rate of ignition and combustion of a charge.

The density depends on the amount of pressure to which the powder meal has been subjected during manufacture, while the hardness is greatly affected by the amount of moisture present in the meal when pressed; one term applies to the mass, while the other refers more particularly to the surface of the grains. A dense powder may be generally stated to be a slow-burning powder, while a hard one is slow lighting. Density retards the combustion, both because there is more matter in the same volume, and consequently more powder to be consumed in proportion to the ignited surface of the grain, and also because the heated gas finds greater difficulty in penetrating the solid mass of the grain. A hard powder need not of necessity be very dense; it is even possible, by pressing it in a moist state, to obtain a very hard powder which shall at the same time be lighted and porous in the interior of the grains. Such is the Russian prismatic powder (of which more hereafter), and it may be taken as a good specimen of a slow lighting but quick burning powder.

With the improved appliances now used in testing powder, the quality of the large stock of L.G. and R.L.G. in store in this country has been found to be very variable, principally due to variation in the density of different brands. Previous to the year 1868, the proof to which all cannon powders were subjected was very imperfect, and failed utterly in insuring uniformity in those passed into the service. The density was only roughly ascertained by the process of "cubing," as it was called, while the strength and uniformity of the powder was tested by the "Mortar Eprouvette." "Cubing" consisted in weighing a cubic foot of the powder, a box made to hold that amount being filled by pouring the substance loosely into it; the weight therefore depended, to a great extent, upon the closeness with which the powder packed itself, as well as upon the absolute density of the grains. The shape of the grains, and the amount of glaze the powder has received, affect the closeness with which it packs itself, and would therefore lead to errors in determining the density in this way. At the present time the density is accurately arrived at, by means of a mercury densimeter, in which the weight of a given volume of powder is compared with that of an equal volume of mercury; the density of mercury (corrected according to the readings of a barometer and thermometer at the time) being known, that of the powder is easily calculated.

In the "Mortar Eprouvette" a round shot, weighing 68 lbs., was fired from an 8-inch mortar with a charge of from 2 to 3 oz. of the powder under examination, and the range of the shot from the muzzle of the mortar was measured. The greater the range the better was the powder believed to be, the only limit being a low one. The fallacy of this belief was proved beyond a doubt as early as the year 1864, by comparing the velocity of shot fired with different powders, by means of the accurate instruments then generally in use for that purpose. It was then found that powders which gave the best results in very small charges fired from a mortar were often very inferior when fired in comparatively large charges from guns, and the immediate adoption of a new proof of powder, by measuring the velocity of shot fired under service conditions, was strongly recommended. This recommendation was not, however, carried out until four years later, when Colonel Younghusband, the present Superintendent of the Government Gunpowder Works at Waltham Abbey, introduced the velocity proof which is now in force. The instrument used at Waltham Abbey for measuring the velocity of a shot is an electroballistic chronoscope, invented by Captain Le Bouleugé, of the Belgian Artillery, which surpasses all similar instruments in simplicity and facility of manipulation, though the principle upon which it acts is the same as in others. In it electricity is employed to record the exact instant at which the shot passes two points at a known distance apart, a short space in front of the gun. From this the time occupied by the shot in traversing the distance between these two points is known, and the velocity with which it is moving is readily ascertained, and affords a direct indication of the strength and uniformity of the powder. Every kind of powder now passed into the service is subjected to this proof, in addi-

tion to being tested by the mercury densimeter.

We have stated that R. L. G. powder was adopted in 1860 for our breech-loading guns, and that its use was afterwards extended to the charges of all rifled guns.

When, however, the size of our heavy ordnance was increased more and more, it soon became apparent that even this powder was totally unfit for the large charges then used, and its violent action earned for it abroad the unenviable *sobriquet* of "*poudre brutale.*"

In the year 1858 the gunpowder question was referred to a committee, composed of the Superintendent of the Royal Gunpowder Factory, the Superintendent of the Royal Laboratory, and the Chemist to the War Department, and it was, in fact, some of the earlier experiments of this committee that led to the introduction of A_1 or R. L. G. powder. The means at their disposal for determining the manner of combustion, and the pressure exerted upon the gun by different kinds of powder, were very limited. Nevertheless, the conclusions they arrived at, as set forth in their reports of 1859 and 1866, were very correct, and have been entirely corroborated by subsequent researches. As early as 1860 they had satisfactorily proved that the density and hardness of powder exercise an important influence on its character, and in all their subsequent experiments these points were strictly attended to. In their final report (1866) they recommended the adoption of a cylindrical "Pellet" powder of a density between 1.492 and 1.50, but pressed comparatively wet, so that, though light, the powder should be rather hard. This powder was adopted entirely upon experiments carried on with various natures of Armstrong breech-loading guns and smooth-bored mortars, and it is evident that a light, but hard, powder, such as this is, which would be slow lighting but quick burning, would be exactly suited to breech-loading guns, in which the initial resistance of the tight-fitting, lead-coated projectile is very great, as the lead has to be bodily forced forward into the grooves of the rifling.

The pellet form was recommended principally as a convenient method of making a large grain powder of considerable uniformity in size and density; but the committee did not consider that the subject of gunpowder had been exhausted by them, and closed their report with a recommendation that "systematic artillery experiments should be instituted with this pellet powder, of a sufficiently comprehensive character to test thoroughly the system."

In the meantime, while the labors of the committee were still progressing, other experiments were being carried on in this country. In 1863–4 a proposal was made to press granulated powder into discs the size of the bore of the gun, and perforated with holes to facilitate the passage of the gas. These discs varied in thickness from 2 to 3 in., and were made of powder of various-sized grains, the amount of the compressing force differing in different specimens. The results of these trials were not sufficiently satisfactory to lead to the adoption of this form of powder. About the same time a similar description of powder, proposed by Dr. Doremus, an American, was tried unsuccessfully, both in America and in this country; and again, in 1866, discs—made by compressing the powder meal—gave even less satisfactory results.

The Americans, about this period, introduced an irregular large grain powder, which they called "Mammoth," and still use in the large charges fired from their enormous cast-iron smooth-bored guns, to which they obstinately adhered for years after the remainder of the civilized world had been armed with rifled ordnance of wrought-iron or steel. The size of this powder ranges from 0.15 in. to 0.30 in. and its density is very moderate, being 1.70 to 1. 75.

"Prismatic" powder appears, also, to have been tried in America in 1865; it had already been fired with good results from the heavy steel breech-loading guns which the Russians and Prussians have obtained from Messrs. Krupp, of Essen. This powder is shown at Fig. 2, Plate I., being made in the form of regular hexagonal prisms about 1 in. thick and 0.8 in. in the side, perforated with 7 holes about 0.1 in. in diameter. In making up charges of this powder, the prisms are built up regularly in the cartridge bags, like honeycomb, which are then tightly tied at the mouth, so that the grains are kept firmly in their place. The perforations thus form long tubes through the charge,

by which the gas permeates the whole mass.

The powder meal is pressed into the shape of these prisms in a very moist state, but the pressure is not great, as the density of the finished powder is only 1.67. The surface is, however, very hard, and being, to a certain extent, covered with a film of saltpetre, which is deposited by the moisture when the powder is dried, it is comparatively difficult to ignite; when once inflamed it burns very rapidly, being light and porous, and in this respect is very like the pellet powder recommended in 1866, being particularly suitable for breech-loading guns. Though this pellet powder was decidedly a step in the right direction, as the strain upon our guns was considerably reduced by its use, it was only nominally adopted into the service in 1867, and was never issued either to our ships or batteries. The reason for this was, that there existed no machinery for manufacturing a sufficient supply, and, while the necessary machinery was in preparation, the results of the experiments of the present Committee on Explosives led to its abandonment in favor of "pebble" powder.

This committee was appointed in May, 1869, to inquire generally into the value of various explosive substances, such as gun-cotton, nitro-glycerine, etc., in use, or proposed, for military purposes, and more particularly into the powder question, in which, through mismanagement rather than ignorance, we had fallen behind the rest of Europe. They at once entered on an extended series of experiments, with a view to the "determination of the description of gunpowder whose employment in large charges is attended with the least risk of overstraining the heavy guns" we now employ, and have rendered two preliminary reports on this subject*. From these it appears that no less than 40 descriptions of British and foreign powders have been fired in large charges from heavy guns, out of which number 4 varieties were selected for further experiments.

The guns used in these experiments are an 8-in. wrought-iron smooth bore of 6½ tons, and a 10-in. gun of 18 tons; the latter was first used as a smooth bore, and afterwards rifled.

The means employed by the committee, in the investigation of the action of the large charges fired from these guns, are very ingenious, and may be briefly described as follows:

1. The determination of the time taken by a projectile in traversing various intervals within the bore of the gun, which was effected by means of a chronoscope invented by Capt. A. Noble, a member of the committee, and made at the Elswick Ordnance Company's Works. This will be described hereafter.

2. The determination of the pressure directly, by means of Rodman's pressure-gauge fitting on the exterior of the gun, and communicating with the interior of the bore by means of a hollow screw-plug.

3. The determination of the pressure directly, by means of an inner gauge termed a "crusher," which was designed by the committee to overcome certain defects inherent in the Rodman gauge.

4. The determination of the velocity of the projectile after leaving the gun, by means of Navez-Leur's or Le Boulengé's electro-ballistic apparatus, commonly used for this purpose.

The principle of action of the chronoscope consists in registering, by means of electric currents, upon a recording surface, travelling at a uniform and very high speed, the precise instant at which a shot passes certain defined points in the bore. The instrument may be divided into two portions: the one consisting of the mechanical arrangement for obtaining the necessary speed, and keeping that speed uniform; the other forming the electrical recording arrangement.

The first consists of a series of thin metal discs, each 36 in. in circumference, fixed at intervals upon a horizontal shaft, which is driven at a high speed by a heavy weight, arranged according to a plan originally proposed by Huyghens, through a train of gearing multiplying 625 times. The driving weight is continually wound up during the experiment by means of the handle, and the requisite speed is obtained by accelerating the motion by the handle. The precise rate at which the discs are moving is ascertained by the stop-cock, which can, at pleasure, be connected, or disconnected, with the

* "Preliminary Report of the Committee on Explosive Substances"; printed at the War Office, February, 1870; and Progress Report of the same, January, 1871.

revolving shaft, and the time of making any number of revolutions of this shaft can be recorded with accuracy to the $\frac{1}{10}$ part of a second.

The speed attained is generally about 1,000 in. per second linear velocity at the circumference of the revolving discs, so that each inch represents the 1-1,000th part of a second, and, as the inch is subdivided by the vernier, into a thousand parts, a linear representation is thus obtained at the circumference of the discs of intervals of time as minute as the *one-millionth part of a second.* As a small variation in speed would affect the relations between the several records obtained, the uniformity of rotation is ascertained, on each occasion of experiment, by 3 observations—one immediately before, one during, and one immediately after the experiment, the mean of the 3 observations being taken as the average speed. The accuracy of the workmanship in the instrument is shown by the great degree of uniformity at which the speed is maintained. The Report gives the observations in 6 consecutive rounds; in 2 of these the speed was absolutely uniform, while the greatest variation in any round is as follows:

1st	observation.	625	revs.	made	in 21.2	secs.
2d	"	"	"	"	20.9	"
3d	"	"	"	"	20.7	"

The arrangement for obtaining the electrical records is as follows:—The edges of the discs are covered with a strip of white paper, and each is connected with one of the secondary wires of an induction coil. The secondary wire, carefully insulated, is brought to a discharger, opposite the edge of its corresponding disc, and is fixed so as to be just clear of the latter. The surface of the paper on the discs is coated with lamp-black, so that the passage of a spark from the discharge to the disc burns away the black, and marks the spot perforated by exposure of the white paper beneath.

In order to connect the primary wires of the induction coils with the bore of the gun, so that they may be cut by the shot in its passage, the gun has been tapped in a number of places for the reception of hollow steel plugs, carrying at the end next the bore a cutter which projects slightly into the bore. This cutter is held in position by the primary wire, which is carefully insulated and passed down the plug, through the cutter, and back out of the plug, the ends being connected to the main wires leading to the induction coils. When the shot reaches the point where a plug is screwed in, it presses the cutter in flush with the bore, and, by so doing, cuts the primary circuit, thereby causing an induced spark to pass from one of the dischargers to the corresponding disc. As each plug is reached, a spark is delivered on the disc in connection with it, and thus the passage of the shot up the bore is recorded at regular intervals. By means of the micrometer, v, the distance between the sparks on the discs is read off, each spot being brought in succession exactly opposite the discharger belonging to the disc it is on; the speed at which the discs are moving being known, the time occupied by the shot in passing from one point to another is readily ascertained, and its velocity of translation calculated.

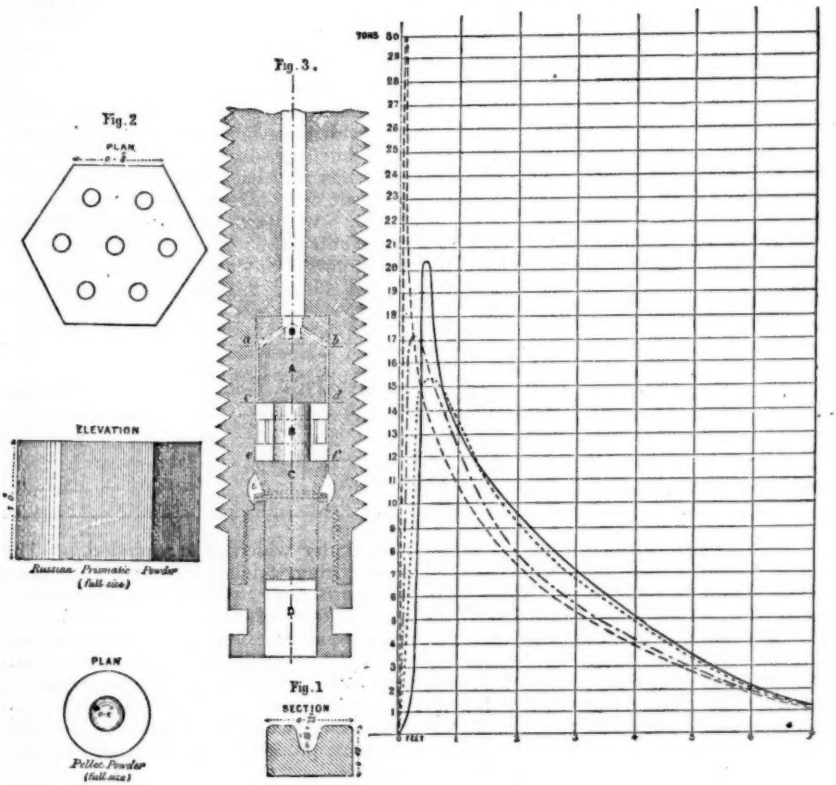
In order to test the accuracy of the instrument, it is only necessary to cut the whole of the primary wires simultaneously, when the whole of the sparks should be in one straight line, and the deviations from a straight line, that is, from an absolutely simultaneous record, give the instrumental errors.

Great difficulties were experienced in securing a simultaneous rupture of the primary wires, and only two methods were found at all satisfactory. One arrangement was to cut the wires by a flat-headed bullet fired from a rifle, across the muzzle of which they were all tightly stretched; in the other they were all wound round a detonating fuze, the explosion of which severed them almost instantaneously. A number of the observations thus obtained are given in the Report, and the errors—including those due to the impossibility of obtaining an absolutely instantaneous rupture of all the wires—seldom exceed 0.000003 sec., while the maximum error is only 0.00002 sec.!

In addition to the holes tapped to receive the cutting-plugs already described, the gun is also bored to take a number of Rodman or "crusher" gauges. When any of these holes, which are 21 in number, were not required in the experiments, they were filled with solid steel plugs. The Rodman pressure gauge consists of a piston, working in a hollow screw plug open to the bore, the outer end of

which carries a pointed knife, against which a piece of copper is placed. When the gun is fired, the gaseous pressure on the base of the piston forces the knife into the copper, and the indent is a measure of the pressure which has acted on the base of the plug. In this instrument the gas has a considerable space to travel between the powder chamber and the piston; thus, before reaching the latter it attains a high *vis viva*, especially in quick burning powders, and acts upon the piston more like a blow than a pressure, and the records are therefore much higher than should be the case.

To remedy this defect the "crusher" gauge was devised by the Committee (see Fig. 3): the reduced dimensions of this instrument allow it to be placed so close to the bore of the gun that the gas has no space to travel before reaching the piston. It consists of a screw-plug of steel, having a movable base which admits of the insertion of a small copper cylinder, B. One end of this cylinder rests against an anvil, A, while the other is acted upon by a movable piston, C, which is kept tight against the cylinder by the spring, *i*. The cylinder is retained in the centre of the chamber, *c*, *d*, *e*, *f*, by a small watch-spring.



A gas-check, D, is inserted against the lower extremity of the piston, and should any gas get past this there are passages by which it can escape into the open air. Upon the explosion of the charge the gas, acting on the area of the piston, crushes the copper against the anvil, and, the amount of pressure required to produce a definite amount of compression of the copper having been determined by previous experiments, the pressure on the piston is at once ascertained. The area of the

copper cylinders used in the 8-in. gun was 1-12th of a square inch, and that of the piston 1-6th of a square inch.

We have stated that 4 varieties of powders were chosen out of a large number for further experiment: these were—R. L.G. service powder, pellet service powder, Russian prismatic powder, and "pebble" powder No. 5. When fired from the 8 in. gun, in charges which best suited each kind of powder, the following results were obtained :—

Nature of Powder.	Charge.	Muzzle Velocity.	Maximu Pressure.
	Lbs.	Feet.	Tons.
R L. O.	30	1324	29.8
Russian Prismatic ..	32	1366	20 5
Service pellet.....	30	1338	17.4
Pebble No. 5.....	35	1374	15 4

From this table it is evident that the Service R.L.G. is far inferior to all the others, while the pebble is manifestly the best.

"Pebble" powder, so called from its resemblance to small black pebbles, was first tried in Belgium, but the powder which gave the above satisfactory results is an improvement on the foreign powder, being more uniform in size and density. It consists of irregular cubes, having edges from 5-8ths to 4-8ths in. in length, made by cutting up the "press-cake" into the required form; the powder is as usual glazed in a revolving barrel, which operation removes the sharp edges. Its manufacture is therefore very simple, little or no new machinery is required for its production, and it is cheaper than any of the other descriptions. Its density is high, about 1.8, but owing to its large size and comparatively uneven surface it is a quick lighting powder: the whole charge (if of the proper form) is quickly and uniformly lighted, and the maximum pressure in the powder chamber is consequently even throughout its surface, while with powders which are both quick lighting and quick burning, like the old L.G. and R. L.G., intense local pressures, varying in different parts of the chamber, are produced. As an example of this the following results obtained in the 10 in. gun in its smooth bore state are given.

Powder and Charge.	Rounds.	Muzzle Velocity.	Pressure per Square inch by Crusher Gauge at.		
			A. Axis of Bore.	B. Centre of Charge.	C. Front of Charge.
		Feet.	Tons.	Tons.	Tons.
L. G. 60 lbs....	6	1273	49	28	29
Pellet 64 lbs.....	3	1377	21½	21	21
Pebble 70 lbs.....	6	1435	22	22	23

The explanation of these local pressures caused by quick burning powders is very clearly stated by Captain A. Noble, in a paper read at the Royal Institution, on the "Tension of Fired Gunpowder," and may be expressed briefly as follows :—The products of combustion of the first portion of the powder inflamed, in travelling from one end of the chamber to the other, attain a very high velocity before meeting with any resistance, and the reconversion of the *vis viva* thus acquired into pressure at the base of the shot and the end of the bore, gives rise to the intense local pressures at those points, while the rapidity of combustion of the powder at that part of the charge is probably enormously accelerated by the tension under which it is exploded. "The time during which these abnormal pressures are kept up must be exceedingly minute, even when compared with the infinitesimal times we are considering; for we find the chronoscope pressure, which may be regarded as representing the mean of pressures of a violent oscillatory character, hardly altered at all, even although the local pressures are increased 50 per cent.

In the figure a representation is given of the pressure curves calculated from the chronoscope observations, and in the following table the pressures in tons shown by the crusher gauge are compared with those obtained by the chronoscope in the 10 in. gun.

CHARGE.	Muzzle Velocity.	Total Work on Shot.	Pressure per Square Inch at A. By Gauge.	A. By Chronoscope.	B. By Gauge.	B. By Chronoscope.	C. By Gauge.	C. By Chronoscope.	Mean of B and C. By Gauge.	Mean of B and C. By Chronoscope.	1. By Gauge.	1. By Chronoscope.	4. By Gauge.	4. By Chronoscope.	10. By Gauge.	10. By Chronoscope.	14. By Gauge.	14. By Chronoscope.
R. L. G.—60 lbs. D 1.742.....	1327	4824	51.4	..	32 5	..	26.3	..	29.4	24.3	..	10.5	12.4	8.9	4 8	6.5	3.2	4 5
Pellet—64 lbs. D. 1.677	1374	5164	25 0	..	22.9	..	20.1	..	21.5	22.2	..	10.4	11.2	9.0	5 2	6.3	..	4 3
Prismatic—61 lbs.....	1344	4947	18.9	..	17.7	..	18.0	..	17.9	19.3	14.7	12.3	12.0	9.9	7 0	7.0	3 7	4.9
W. A. Pebble—70 lbs. D. 1.782...	1442	5384	20.9	..	21.3	..	20.0	..	20.7	21.9	16.0	13.5	12.2	11 4	9.0	8.2	4.0	5.0

The letters and numbers refer to the plugs, reading from breech to muzzle, and it is evident that, with the mild kinds of powder, the mean maximum pressure in the powder chamber, and also the pressure at different parts of the gun, arrived at by these two perfectly different methods of observation, agree very closely; while the intense local, or wave, action of the violent R.L.G. is also very apparent. The intensity of this local action depends, moreover, in a great measure upon the length of the cartridge; if this be excessive, these objectionable strains at once begin to appear even in the case of pellet or pebble powder, as has been clearly demonstrated in the 11.6-in. 35-ton gun, firing 120 and 130 lbs. of powder, and also in the 10-in. gun when tried with proof-charges of 87.5 lbs.

The specification upon which pebble powder is received from the trade is very strict. Not only must the powder be very uniform in size and density of grain, but it is also further tested by firing battering charges (35 lbs.) of every supply from an 8-in. gun, when the pressure in any part of the powder chamber must not exceed 20 tons on the sq. in., and the variations in velocity must be comprised within narrow limits. By thus severely testing the whole of our supply of this new powder, the committee are able to insure that it shall never depart in any important degree from the required standard. The admirable results obtained in the 8-in. and 10-in. guns with pebble powder have been maintained in all the heavier natures, insomuch that the use of this powder, while materially reducing the strain upon the guns below that caused by R.L.G., has at the same time augmented their power to a very considerable extent, as shown in the following table:

Nature of Gun.	Charge, lbs. R. L. G.	Charge, lbs. Pebble.	Mean Pressure per Square Inch in Powder Chamber. R. L. G.	Mean Pressure per Square Inch in Powder Chamber. Pebble.	Muzzle Velocity. R. L. G.	Muzzle Velocity. Pebble.	Total Energy of Shot. R. L. G.	Total Energy of Shot. Pebble.
	Lbs.	Lbs.	Tons.	Tons.	Feet.	Feet.	Ft.-tons.	Ft.-tons
12 in., 25 tons... ...	67	85	23	19	1180	1300	5793	7030
10 " 18 "	60	70	32	23	1298	1364	4693	5160
9 " 12 "	43	50	21	15	1336	1420	3094	3496
8 " 9 "	30	35	30	20	1363	1413	2319	2492
7 " 6⅛"	22	30	17	10	1430	1525	1631	1855

With this, the result of the experiments of the last fourteen years, we will leave the subject, though there are many other points of scientific and practical interest to artillerymen which have been set at rest by the committee's researches, while there are others which they are at the present moment investigating.

At one period, as we have already stated, this country was allowed to fall behind

some foreign nations in the all-important question of powder for heavy guns, and the capabilities of our magnificent Naval Ordnance were sacrificed, and their endurance endangered, by the use of a variable and violent powder. All this has now been set right, and it is satisfactory to feel that our ships and forts are not only armed with the best guns in existence, but that they are also being rapidly supplied with a powder in every respect suitable for their use.

A DECADE OF STEAM ROAD-ROLLING IN PARIS.

From "The Engineer."

That great improvement in ordinary macadamization, consisting in rolling the layers of broken stone by heavy steam rollers, is now making comparatively rapid headway in England. The process is attracting such attention that a valuable paper on the subject, contributed by a French company, Messrs. Gellerat and Co., of Paris, which has given the initiative, will be studied with interest by many. The municipalities of Liverpool, Glasgow, Manchester, Leeds, Sheffield, and Maidstone, and others, now possess and use steam road-rollers, and the process has already been tried on a more or less extensive scale in at the very least 7 metropolitan districts.

THE CONTRACT WITH THE CITY OF PARIS.

As long ago as 1860 experiments in road-rolling by steam engines were made in Paris. These experiments, again taken up in 1864, and continued by Messrs. Gellerat and Co., induced, in consequence of comparative trials between horse road-rolling and steam road-rolling, the engineers employed by the Paris municipality to conclude, in 1865, a contract with the company. This has given both extension and a regular and permanent character to the application of this process. The contract, made for 6 years, obliges the company to keep permanently at the disposal of the city of Paris 7 steam road-rollers of the construction patented by them. These rollers are principally intended for rolling the macadamized roads of Paris and of the Bois de Boulogne and Bois de Vincennes ; but they can also be used for setting paving stones and for rolling the foundations of paved roads. The contract fixes the maximum and minimum diameters of the 2 carrying rollers of each engine, the maximum width of the machine, the speed of travel of the engines, and the weight per metre run of the width of the external diameter of the carrying rollers. The work done is paid in the compound ratios of the distance traversed by the engine at work on broken stone to be rolled, and of the weight of the engine itself. The unit of the accounts is the kilometric-tonne ; that is to say, 1,000 kilogrammes of the weight of the engine carried a distance of 1,000 metres. This unit is paid for at the rate of 0.50 f. during the night and 0.45 f. during the day. As regards the average weight of the engines, it is determined by weighing, checked by both parties to the contract, and the distance passed over is given by a counter driven off the rollers.

THE DISTINCTIVE CHARACTER OF THE PARISIAN STEAM-ROLLERS.

The distinctive qualities of the rolling engines employed in Paris are :—The entire utilization, for the progression of the machine, of its weight; and the identity of the front and hind parts of the engine—an identity which allows it to work with the same ease in both directions, and, consequently, to advance in either direction without turning round. The 2 carrying rollers are both drivers, and are propelled in the same way, but separately, by the steam engine. We have to add that the engines can turn in a minimum radius of from 10 to 15 metres—32 ft. to 48 ft.—according to their dimensions. Thus, with their power of going either backwards or forwards, this allows them to work in the most narrow streets and to pass the sharpest corners. The application of the whole weight for obtaining adhesion gives the Gellerat Company's engine great traction power, a power often entirely called into play, especially when the metalling is of bad quality and the foundation of a yielding nature. A steam road-roller without this power would often be incapable of moving itself on freshly laid metalling,

and, *a fortiori*, of dragging itself out of the many difficult positions to be encountered in making new roads. The average weights of the Gellerat engines, in the order in which they are used, are 17, 34, and 30 tonnes of 1,000 kilogrammes—in English weights, 16 tons 14 cwt. 2.5 qr.; 25 tons 12 cwt. and 1.6 qr.. and 29 tons 10 cwt. and 2.094 qr. respectively. The weights per metre run of the rollers are 6,000 kilogrammes for the smallest engines, and 8,000 kilogrammes for the two other sizes. Engines of these graduated sizes have been able to execute all the work which has offered itself up to this day. The lighter engines are more particularly suited for new work under difficult conditions; the heavier rollers, which can also be used on new work, are more suited for maintaining roads. They can roll in a single night a very considerable road surface. The maximum speed with which the engines are to work has been fixed at 4 kilometres, or 2 miles 854.5 yards per hour. This speed, but seldom attained, is still less commonly exceeded. We may estimate, as a general rule, the speed of 3 kilometres, or 1 mile 1,520 yards per hour as the average velocity developed from the beginning to the end of an ordinary day's work. Rather less at the beginning, when the draught is considerable, it increases with the degree the binding of the road approaches completion.

WORK DONE IN PARIS.

Since 1866 there has been steam-rolled in Paris a total volume of 32,000 cubic metres, or 41,857 cubic yards of metalling of different kinds, such as flints, gravel, broken stones, more or less hard millstone grit, porphyry, and trap—the last a metamorphic quartz rock. These different materials are all rolled in the same way, with slight differences depending on the manner they behave under the action of the rollers. Pebbles and gravel, which at the outset are very movable under the rollers, form a wave in its front. A small quantity of water is sometimes sufficient to diminish this tendency; pebbles bind easily with the addition of sand. These last materials are cheaper than those generally used in Paris, but they are much employed for keeping up roads subjected to considerable traffic. Millstone grit, still more binding than the preceding materials, is easily rolled, and affords an easy draught and ready maintenance. Porphyry and trap, being much harder, require to be longer rolled. The crushing together of the materials is slower, and the binding more difficult; but when this double result is obtained the road offers a considerable resistance. On these materials the heavier engines are particularly efficacious.

NUMBER OF KILOMETRIC TONNES REQUIRED FOR STEAM ROAD-ROLLING.

It results from observations made since 1866 that, on an average, 6 kilometric tonnes are employed in Paris to roll one cubic metre of any material of whatever kind. The amount of load varies according to circumstances, from 3 tonnes, and even 2½ tonnes, up to 20 and 30 tonnes. The necessity for the latter large amounts can only be explained by a bad management of the operation, and principally by the circumstance that an insufficient amount of work is sometimes given to the engines for rolling, from which it follows that the later hours of the operation are badly or not at all utilized. It is now recognized that when the operation is well conducted it is possible to do excellent rolling with an expenditure, at the most, of from 4 to 5 kilometric tonnes per cubic metre rolled. Any little deviations are to be explained by the state of the weather, by the greater or less quantity of the matters of aggregation employed, by more or less irregularity in the watering—in one word, by the mode of working. But neither the nature of the materials nor the thickness of the layer seems to exercise a sensible influence on the result, if the rolling of one cubic metre be taken as the unit of the work done.

HOW THE OPERATION SHOULD BE CONDUCTED.

It is necessary to make a distinction between rolling new roads and rolling fresh layers on old roads. New roads constructed after the clearing away of old houses, as has been so much the case in Paris, are difficult to roll. They pass over old cellars filled up with rubbish; and the subsidences, which would in any case be very unequal, are particularly so when the filling up operations are not very carefully done, or when substances non-homogeneous, or of bad quality, as often happens in Paris, are used. It is then that the smaller form of engine is

employed with advantage; it presses with less force on the ground and runs less chance of sinking down. The foundations of new roads are also often rolled. This is sometimes done in two layers, rolled one after the other, and in some cases only one layer. The first plan is by preference employed when the first layer is formed of less resisting materials; the second when the road is homogeneous. These different operations generally proceed with ease, provided care has been taken not to water too much at the beginning in order not to excessively soften the soil. The rules to be followed for watering, sanding, and rolling, do not much differ from those applicable to fresh coatings of metalling on old road surfaces. Fresh coatings used to be and still are put down principally during the rainy weather of the spring and autumn. Now that water is taken over all Paris, roads can be coated afresh, and rolled the year round, excepting during frost or seasons of great drought. When any road has arrived at such a degree of deterioration as to require a fresh coating of metalling, the surface, if the weather is not wet, is softened by abundantly watering. The picking up is then proceeded with. This consists in picking up by means of pick-axes the beaten crust of the road in order to permit the layer of fresh materials to closely bind itself with the existing old surface. The work of picking up varies with the hardness of the materials comprising the old road. It is often done by the piece. Each man takes a surface of from 20 to 30 metres—24 to 35 square yards—to pick up during a day or night. The work of picking up is hence very dear, and is accordingly often dispensed with. The workman first of all cuts transverse furrows from 0.15 to 0.20—about 5 to 7 in. distant from each other, and then picks up the road by means of smaller furrows perpendicular to the first.

The picking up being completed, the materials are brought in carts and discharged on the road, in such wise as to be equally spread over it with the least possible labor by means of the shovel. The workman then takes the stone from the heaps and spreads it over the required spots, regulating the thickness according to given gauges. An experienced man can spread as much as 10 cubic metres—13 cubic yards—of materials per day. It is also a good thing to have one or several workmen to bring back the stones that the traffic may chance to carry away on to the sides of the road. From distance to distance the whole length of the road, and on both sides, small heaps of sand are so disposed that the sanding can be quickly and equally done. In many cases the road is watered before beginning the operation of rolling; but this watering is not always carried out. Other arrangements adopted by the different employés charged with carrying out the operation of rolling, such as the more or less abundance, and the succession of subsequent waterings, the spreading of the sand at the successive stages in which the road gets bound, are exceedingly variable, and it would be extremely difficult to prescribe any absolute rule. In this operation, as in all others of the kind, there is a certain knack, difficult to describe, but which is pretty easily acquired, and which is not so strictly fixed as to prevent one reaching the goal by different ways. The only secret in managing the work when the sand is of good quality is to attentively follow the binding of the broken stone, and to slacken or increase the watering and spreading of the sand on the parts where the rolling engine is at work.

The quantity of water to be used is very variable, being dependent, as reflection will at once show, on the weather. It would be difficult to give a strict rule for its use. Avoid using too much, especially at the beginning of the work, in order not to drown the bottoming in the course of the operation; use sufficient water to make the stone and sand slightly moist; and towards the end, when the broken stone is bound, and the moisture appears at the surface without penetrating to the interior, abundantly water the road in order to carry off any sand in excess and that to obtain the final smoothness of the surface. Such are nearly all the general directions that can be given. As regards the hogging or sand used for binding, that applied in Paris generally comes off the road itself, and it is also the best.

It must have binding properties without being clayey; the cleaner it is the better, provided it is not too sharp. The road laborers (*cantonniers*) obtain it by

washing the mud of the road. As to the quantity that should be employed in order to make the best rolled road, this also greatly varies in practice. Some throw the gravel on from the beginning rather plentifully, others only begin to use it when the stones are already squeezed together. On the first introduction of macadamized roads the stones were prescribed to be absolutely clean, and the use of any detritus was severely prohibited. This idea has not been adhered to. But generally it can be said that it is better to sin in the direction of too little than of too much binding, and the general tendency in Paris is to reduce the use of binding materials to the lowest quantity possible. Let us merely add that, as regards both sand and water, there is no inconvenience towards the end of the operation, when the binding has taken place, in applying much sand or water respectively during the last passages of the roller. Any excess of sand is carried off by the water.

THE MANAGEMENT OF THE STEAM-ROLLER.

The working of the engine remains to be spoken of. We are here confronted by a rule which is never departed from, whether as regards a road being rolled along its whole breadth, or only half its breadth, though it principally relates to the case in which the whole width is being rolled. The operation is always begun at the sides. The roller at first executes a certain number of passages over one of the edges of the macadam. When the stones begin to be brought together the surface is slightly watered from a barrel or by a jet, and by means of a spade a very thin layer of the sand provided is spread. At each passage the roller is gradually brought nearer to the crown of the road. The operation is continued in this way for some time, and when the one side of the road is sufficiently bound the other is begun with, and brought to the same state as the first. The central part is done last and in the same mode. The roller thus passes over the whole surface, staying longer over those portions less squeezed together than the others. During the operation the road is moderately sanded and watered. As we have said, towards the end the excess of water runs to the surface, taking with it also any excess of binding material. The rollers then produce no impression. By this means a smooth hard road is obtained, and it can be at once open to traffic. The heaviest carts leave no trace.

THE ECONOMY THROUGH STEAM ROAD-ROLLING.

Since the steam roller has been used in Paris the bottoms of the roads have been improved and the duration of the surfaces has much increased. Some roads which, when steam rolling was first employed, were covered with fresh metalling and rolled every 6 months, are now rolled only once a year. This proves a very great economy in the metalling. Steam road-rolling is done in a much shorter time compared with that required for horse road-rolling. It thereby much diminishes the labor required in the necessary operations of watering, sanding, and managing the work. At the same time it prevents the considerable losses produced by the stoppage or the delay of the traffic. This stoppage is otherwise always considerable, whether the stone be spread without rolling it, or whether it is rolled with horses. This loss represents, even without there being very much traffic, a considerable sum. With steam road-rolling, which is done almost entirely during the night, the ends of the streets being closed, only a temporary deviation of the night traffic takes place, without any additional work for vehicles, and with much greater safety for the workmen employed in spreading the stone, in watering and sanding.

WORKING CAPABILITIES OF THE GELLERAT COMPANY'S ENGINES.

According to the indications given above as to the weights of the engines, their average speed, and the number of kilometric tonnes necessary for executing well rolled work, it is easy to determine the cubic contents of the materials that each engine, according to its weight, can roll per hour. The speed being 3 kilometres, and the number of kilometric tonnes required per cubic metre of the metalling being 4, the cubic contents that can be done by each engine is represented by $\frac{3}{4}$ of the weight of the engines expressed in tonnes. Thus :—

For the engine of	17 tonnes..	12.75	cub. metres.
" "	24 " ..	18	" "
" "	30 ..	22.50	"

At Paris, where rolling is carried out in a very complete mode, the volume of the

materials rolled per hour is less than this. It varies from 8 to 10 metres for the light engines, and rises to 15 and 16 metres for the heavier ones. According to the above data, during 10 hours' work on a layer 10 in. thick, the surfaces that can be rolled are as follows :—

Engines of	17	tonnes	12.75 square metres
"	24	"	18.00 "
"	30	"	22.50 "

THE ROLLING STOCK OF THE PENNSYLVANIA RAILROAD.

Written for "Van Nostrand's Magazine."

The following concise statement of the construction, capacity, and durability of the engines and cars of this important line of road, is contributed by Mr. G. Clinton Gardner :

LOCOMOTIVES.

There are seven classes of locomotives designated by the first letters of the alphabet, each having a large portion of their parts interchangeable one class with another—and, in fact, they are really only varieties of 3 well defined types of engines, known respectively as the 8-wheeler, 10-wheeler, and shifter.

The **A** engine, which is the leading engine over the Middle and Philadelphia divisions of the road, that is, between Altoona and Philadelphia, is an 8-wheeler with 17 by 24 in. cylinders, and 5½ ft. drivers, and of this class there are two varieties, the one differing somewhat in plan of boiler and the other having 5 ft. instead of 5½ ft. driving wheels.

The distribution of the weight in this engine is as follows :

On forward drivers	23,400 lbs.
" back "	22,000 "
" truck	26,500 "
Total	71,900 lbs.
Area of grate	35 × 66⅞ in.
Number of flues	143
Length "	11 ft. ⅛ in.
Outside diameter of flues	2¼ in.

The **B** engine is a modification of class **A**, having cylinders 18 by 24 in., and 5 ft. drivers, with a larger boiler. These are called the "Mountain Passenger Helpers," and are used on the eastern slope of the Alleghany Mountains. One of these engines assisting a **C** engine, takes the regular passenger train, usually of 7 cars, of a total weight of 370,000 lbs., from Altoona to the top of the mountain in 24 min., a distance of nearly 12 miles, making an ascent of about 1,000 ft.

Weight of **B** engine, in working order, is distributed as follows :

On forward drivers	24,800 lbs.
" back "	22,900 "
" truck	25,400 "
Total	73,100 lbs.
Area of grate	35 × 72¾ in.
Number of flues	155
Length "	10 ft. 8 in.
Outside diameter	2¼ "

The **C** engine is almost identical with the **B** engine, differing in the size of cylinder, plan of boiler and weight of frames, being also another modification of the **A** engine. They were designed for mixed trains to be used for local and fast freight, but have proved to be the most efficient passenger locomotives on the road, and are now in constant use for that purpose on the Pittsburgh division, that is between Altoona and Pittsburgh. An idea of the power of these engines may be formed from the fact that in ascending the western slope of the mountain on an average grade of 45 ft. to the mile, with a train of 9 cars, weighing about 487,000 lbs. it has frequently evaporated 24 hundred gallons of water in less than one hour.

The weight of the **C** class is distributed as follows:

On forward drivers	23,200 lbs.
" back "	22,600 "
" truck	25,500 "
Total weight	71,300 lbs.
Area of grate	35 × 72½ in.
Number of flues	151
Length of "	11 ft. ¾ in.
Diameter "	2¼ "

The **D** engine is the standard ten-wheel freight engine, having cylinders of 18 by 22 in. with 4½ ft. drivers. These engines are used on all portions of the road except the mountain.

The total weight of the **D** engine, in working order, is as follows:

On forward drivers	18,000 lbs.
" main "	18,300 "
" back "	18,200 "
" truck	20,800 "
Total weight	75,300 lbs.
Area of grate	35 × 60 in.
Number of flues	119

The **E** engine is the standard "Mountain Freight," being a modification of the **D** engine, differing only in the drivers, and boiler. The drivers are 4 ft. instead of 4½, and the boiler is larger. These engines are chiefly in use on the mountain; upon the trial of one of them she took a train weighing (exclusive of engine and tender) 500,000 lbs. from Altoona to Gallibzen, a distance of 11 and 8-10ths miles, in 35 min., ascending a maximum grade of 96 ft. to the mile, making a total ascent of 983 ft. The regular load over this part of the road is 418,000 lbs.

The weight is distributed thus:

On forward drivers	19,200 lbs.
" main "	19,400 "
" back "	18,000 "
" truck	19,000 "
Total weight	75,600 lbs.
Area of grate	35 × 67¼ in.
Number of flues	123
Length "	12 ft 3¾ "
Outside diameter	2⅛ "

The **F** engine is a 6-wheel shifter with cylinders 15 by 18 in. and 44 in. drivers. These engines are used in making up, assorting and distributing the trains at the different yards.

Its weight, in working order, is 63,500 lbs., distributed as follows:

On forward drivers	19,350 lbs.
" main "	22,450 "
" back "	21,700 "
Total weight	63,500 lbs.
Area of grate	35 × 44¼ in.
Number of flues	89
Length "	12 ft. 6 in.
Diameter	2¼ "

The **G** engine is a small class designed for construction trains and styled "Light Passenger or Ballast Engine." It has cylinders 15 by 22, with 55 in. drivers, and is mostly used for passenger and mixed service on accommodation trains or branch roads.

Its weight

On forward drivers	19,400 lbs.
" back "	19,800 "
" truck	20,800 "
Total	60,000 lbs.
Area of grate	35 × 55 in.
Number of flues	130
Length "	9 ft. 8 in.
Diameter	2 "

With all these classes of locomotives the principal castings, such as driving boxes, eccentrics, eccentric straps, etc., etc. are common, and to give an idea of their uniformity it is only necessary to state the fact that the number of patterns required for one engine is 112, while the total number required for the 7 classes is only 187; this is exclusive of the tender, which is alike for all. This, the present system of plans and classification has been followed since 1867, and the necessity for establishing some standards became apparent from the fact that five years ago the total number of 380 engines comprised 52 kinds, of which there were two or more of each and 71 odd engines; that is engines peculiar in some particular; whereas at the present time, when the engines number 496, there are but 38 kinds differing from the 7 classes (with many of these varieties of the 7 classes), and but 13 odd engines.

The trucks of these locomotives are of the variety known as the "swing centre"—the socket in which the centre pin or pivot of the engine rests has a lateral motion instead of being rigid as in the old-fashioned truck, and is suspended on links so that in passing around a curve of 350 ft. radius, which they readily do without straining either the engine or the truck, the centre line of the engine lies outside of the centre of the truck. The lateral motion also reduces the severity of a blow from guard rails, frogs, etc., upon the flange of the wheels. Chilled wheels only are used under all trucks, as it was found upon the trial of steel wheels, they would not stand the severe labor of guiding the locomotives over our crooked roads. One chilled wheel proved equal in wear to three steel wheels, and as the breakage of a truck wheel is very rare, the chilled wheels in use were thought to be the safest. The flanges of chilled wheels are soon worn smooth and highly polished, whereas those of steel wheels become rough and torn, wearing in a short time too thin and sharp for safety.

The driving wheels of the standard engines are of cast iron centres, with hollow spokes, counterbalanced with lead, and have steel tires, with the exception of those of the shifting engine, class **F**. It was found necessary to use chilled tires with these, for the same reason that chilled wheels were required for the trucks. In designing these engines, the steel tire being held in high estimation, the desire to use them whenever possible has been a controlling influence in determining the char-

acter of the engine. Having established the fact that an engine could not be guided by steel flanges, it became necessary to place the driving wheels far enough back from the cylinders to allow the entire duty of guiding the engine to be performed by the truck. Numerous efforts have been made to utilize the weight over the trucks for tractive purposes, but without success, except in connection with chilled tires, and they, being a great source of trouble, have been avoided as much as possible, not on account of breaking, but because they became loose and flat.

The locomotive boilers are made of soft crucible steel, the shell of the larger ones being 3-8ths and the other 5-16ths of an inch thick. The fire-box or furnace sheets are also of steel $\frac{1}{4}$ in. thick, with the exception of the tube or flue sheet, which has a thickness of $\frac{1}{2}$ in. and the tubes or flues are invariably of number 11 iron; sometimes the flue sheets are made of copper, $\frac{3}{4}$ in. thick, and the majority of the boilers have a combustion chamber from 4 to 6 in. long, to avoid exposing the thick metal of the flue sheet to the direct action of the fire.

In the construction of these boilers there are no braces between the crown of the furnace and the roof of the boiler, the entire strain on the top of the fire-box being borne by the crown bars and thence transmitted by the sides to the bottom ring. This practice, in use here several years, is believed to be stronger than the old custom of connecting the crown of the fire-box with the roof of the boiler, as it is a fact that no boilers have exploded on this road in which these braces have been left out, whereas the explosions we have had were with those boilers having these braces. This practice, however, would not be safe for copper fire-boxes, as they become very weak when old. The old-fashioned method of putting in fire-box stays is used, and the stay bolts are of $\frac{7}{8}$ iron spaced $4\frac{1}{2}$ by $4\frac{1}{2}$ in., or less, screwed through the sides and headed over, the screws having 12 threads to the inch. The furnace is supplied with water-grates, being tubes of $1\frac{7}{8}$ in. outside diameter, placed $3\frac{1}{10}$ in. from centre to centre. This kind of grate has been in use for a long time, and will outlast the furnace if kept free from mud, and the grate being very open, it is rarely necessary for the fireman to touch the fire with a poker. Opposite each tube there are screw-plugs for washing out the watergrates and removing all scale or mud that may accumulate, which is done at intervals of from 1 to 4 weeks, depending upon the water-station from which the suply of water is obtained. The feed water is supplied by 1 pump and 1 injector.

The steel of which these boilers are made is tested by having a sample from each sheet heated to redness, then plunged into cold water; after which, the same piece, while cold, is bent double and hammered flat. This steel does not acquire any temper whatever by being heated to redness and dipped in cold water, but will bend double afterwards just as well as before. It is not necessary, however, to have the steel so soft, for if it works well and can be shaped without cracking, that is all that should be required. The flanging of our steel sheets is mostly done by a charcoal fire, and, after flanging, the entire sheet is heated for the purpose of straightening it and relieving the strains. This is important, as the sheets are liable to break if hammered cold without having had the strains taken out by heating. The tensile strength of the steel used is about 90,000 lbs. per sq. in. In addition to the tires and boilers, much steel is used in the other parts of the engines, such as guides, connecting rods, crank pins, axles, etc., all of which, including the tires, are of crucible steel.

With regard to the service of these engines the question has been asked, "what is the life or mileage of a steel fire-box?" This as yet can receive no definite answer. The old fashioned steel fire-boxes, such as were built from 1861 to the spring of 1867, lasted somewhat longer than those made of copper, and upon examining the furnace of an engine which had a new fire-box of English steel in December, 1861, and was run until March, 1871, it was found in quite good condition, and far better than the shell of the boiler, which was 17 years old. There was only one small patch on the left hand edge of the crown sheet, a piece of the flange being cut off and replaced by copper. The steel in this furnace is so hard as to be difficult, if not impossible, to drill, and although doubtless hard to begin with, it is safe to say that use has not made it any softer. The flue sheet is perfectly good,

but that is probably owing to its being set in a combustion chamber of about 2 ft. in length. The total mileage of this furnace was 202,852 miles, and the engine (a small freight engine of Baldwin build, cylinder 17 by 22, with 4½ ft. drivers) being worn out, having been on the road since February, 1856, was cut up to be replaced by one of standard build.

Several steel fire-boxes built since 1861 have, however, been taken out, and one great trouble has been the cracking of the sheets around the fire door, in the flanges of the throat sheet, and sometimes the flanges of the door and crown sheets. By the change which was made in the spring of 1867, it is thought that the trouble with the door sheet has been overcome. The solid ring was abandoned, and since that time more than 100 locomotives have been built without the slightest sign of failure being perceptible about the door. With the solid ring a crack would show itself in about two years, when it became necessary to cut out a piece around the door and replace it with copper. The cracking of the flanges of the throat sheet has also doubtless been done away with by placing the flange on the water side. The intense fire striking the edge of the flange was perhaps the cause of the cracking; the metal evidently becomes highly heated, it may be to redness, and this constant overheating appears to contract the steel until it cracks, usually from the edge to the rivet hole; and if the crack passes beyond the caulking on the water side, it produces a leak that can only be stopped by a patch. The life of a steel fire-box built on our present plan will without doubt be not less than 7 years.

When steel fire-boxes first came in vogue it was the practice of some builders to still use an iron tube plate or flue sheet, and the cracking of these has sometimes been charged to steel. This, perhaps, gave rise to the question as to whether iron tube plates crack between the tube-holes the same as steel. There has not been a single flue sheet made since 1867 that has cracked between the flues, and the reason for substituting copper for steel was mainly the leakage of the flues, particularly of engines having the large and long flue, which are 2½ in. outside diameter and 14 ft. long. This leakage was attributed to insufficient surface of the thin ⅝ in. steel flue sheet, and whatever the real cause was, it is certain that tubes of the same dimension are perfectly tight in copper sheets of ¾ in. thickness. The space between the tubes is usually ⅝ of an inch.

The fuel used upon this road is bituminous coal, mostly of the variety known as "Pittsburgh coal," which is excellent and makes an open dry fire, producing hardly any clinkers. It is reported as producing 8 9/10 lbs. of steam from water at 212 deg. to the lb. of coal, but the result on the road in practice has deen found to be about 6½ lbs. of water to the lb. of coal. The maximum pressure carried is never over 130 lbs. to the sq. in.

All passenger engines have the atmospheric brake attachment, which consists of an upright direct-acting air pump placed on the right hand side of the locomotive, partly under the running board. It is worked by steam from the boiler and pumps air into a receiver placed under the foot-board. The pump is automatic, and as the pressure of air in the receiver is reduced by the application of the brakes its stroke is more rapid—thus the pressure is restored in a very few moments as indicated to the engineer by a gauge in the cab placed just above the steam gauge; with this appliance the stops at stations are more quickly made, thus saving much time. On the Pittsburgh Division the passenger engines take their water from water-troughs while running, which also reduces the delays, giving quicker time without increase of speed. These troughs are 18 in. wide and 4 in. deep, placed between the rails on both tracks at two convenient points, and in running over any one of the 4, they being from 1,200 to 1,500 ft. in length, sufficient water to fill the tank is taken.

CARS—PASSENGER EQUIPMENT.

The passenger cars are in no way peculiar, and may be safely considered as a fair representation of the American railroad coach. The style of finish of these cars is changed from time to time, to give a pleasing variety, but the framing and plan of seat is uniform throughout, the one having the necessary strength, while the other gives the comfort so desirable on a long run.

These together with the numerous variety of other cars, such as the open sleeper, the compartment, the double and

single drawing room, the parlor and the silver palace, are capable of furnishing the travelling public with every convenience known to first class railroad travel.

The trucks of all passenger equipment are of the variety known as the "Equalizer truck" and under the ordinary day cars they have two pairs of wheels while those under the sleepers, etc., have three pairs of wheels each. The wheels are made of charcoal iron having a tensile strength averaging not much below 30,000 lbs. per sq. in., and one of these chilled cast-iron wheels weighs about 525 lbs. It is extremely rare that any are broken while in service, their mileage being not less than 100,000 miles, and in comparison with wheels having steel tires, some of which have been tried, there is but slight prospect, if any, of their ever being superseded; the flanges of the steel tires wear rapidly and soon become dangerous.

The axles used are made of soft crucible steel, and are required to stand a test, without breaking, of 5 blows under a drop weighing 1,640 lbs. from he height of 25 ft. One axle from every lot of 50 is taken at random and placed on the supports, 3 ft. apart, under the drop, and struck in the centre, then turned over, always placing the convex side up, carefully measuring the deflection each time, and if it bears the 5 blows without breaking, the lot is accepted.

As an illustration of the quality of this steel the fact may be stated, that on November 15th, 1867, one of these axles was broken with 14 blows—3 at 35 ft., one at 36 ft., two at 38 ft., 7 at 39 ft., and the last one at 40 ft.—the deflection varying from 8½ in. to 11¼ in. These axles are of English make, rough turned all over, 4 in. at the centre and increase to 4¾ in. diameter in the wheel fit—the journal being 3¼ in. by 7 in. These journals each carry about 4,000 lbs. of dead weight, and at most not over 1,000 lbs. of load, that is under the passenger cars. Under the sleepers the dead weight is nearly the same, but the load is not over 325 lbs.

There being no record as yet of the life of these wheels and axles, they are never allowed to run under passenger equipment over 18 months after the date stamped on the axles when placed in service, and after that time they are transferred to freight equipment.

The ordinary passenger car will seat 52 persons, and a sleeper or palace car has 24 double berths, and is consequently capable of accommodating 48 persons, but each berth is very rarely occupied by more than one person. The total weight of a passenger car is 38,000 lbs.; of a sleeper, from 42,000 to 46,000 lbs.; and of a palace car, from 56,000 to 58,000 lbs. The weight of a 4-wheel truck is 6,400 lbs., and of the 6-wheel truck, 9,600 lbs. The mileage of a sleeper is about 10,000 miles per month.

The air or pneumatic brake is in use on all passenger equipment, and works well, giving the engine driver perfect control of the train, enabling him, in an emergency, to stop an ordinary train within its length, say about 500 ft. from the point at which the air is admitted to the cylinders under the cars. The air pressure necessary for all practical purposes is from 55 to 60 lbs. per sq. in., and with care a successful stop can be made with a consumption of about 13 lbs. of air pressure.

In addition to the cars mentioned, the passenger equipment consists of the half passenger or smoking and baggage, the baggage, the mail and baggage, and the express cars, and it frequently becomes necessary to use the freight-box cars for additional express freight, in which case air pipes with the hose connections are used temporarily, to convey the compressed air for air brake under these cars.

All passenger cars are lighted with ordinary coal gas, compressed to about 300 lbs. to the sq. in., and carried in fixed tanks under the body of the car. The two tanks are placed laterally on each side of the car and filled by a hose connection, at the principal stations, from a gas house—the gauge just below the governor in saloon of each car indicating the amount of gas pressure received. Sufficient gas is carried to supply one 3-ft. burner in saloon and four 6-ft. burners in body of car during 12 to 15 hours. These cars are warmed by a stove at each end of the car, burning anthracite coal, so arranged that a current of air is forced in by the motion of the train, and after being heated is distributed by air passages under the seats.

FREIGHT EQUIPMENT.

The freight cars consist of 5 kinds, designated as the "Box Car," "Stock Car," "Gondola," "Drop-bottom Gondola," and "Drop-bottom Coal Car."

The Box car is used for carrying general merchandise, grain (mostly in bulk), flour, etc. The weight of the empty car is 20,000 lbs. and will carry about 16,000 lbs. of grain and from 20 to 24,000 lbs. of flour, 216 lbs. to the barrel.

The Stock or Cattle car weighs about 19,000 lbs. and will carry about 16,000 lbs. of horses or mules, 14,000 to 18,000 lbs. of cattle, 12,000 lbs. of hogs and 9,000 lbs. of sheep. Many of these cars have an upper deck by which means they carry 18,000 lbs. of hogs or 14,000 lbs. of sheep. These cars are also used frequently for rough freight of various kinds, such as oil, pig iron, coal, staves, bark, etc.

The Gondola car and Drop-bottom Gondola are, with the exception of the trap doors, the same, and used for miscellaneous freight, but mostly for coal and timber. The trap doors are for the convenience of unloading coal on trestle work over bins, or chutes, for transshipment. The weight of the Drop-bottom Gondolais from 18,000 to 19,000 lbs., while that of the Gondola is about 2,000 less, and either will carry from 20,000 to 24,000 lbs. of freight.

The "Drop-bottom Coal car" as the name indicates, is used mostly for coal. The dropping of the trap doors of this car will discharge its entire load without shovelling. Its average weight when empty is about 16,000 lbs. and is capable of taking a load of from 20,000 to 24,000 lbs. Iron ores and other kindred substances are also carried in these cars.

In addition to these cars there is a "Maintenance of Way Dirt Dump" used in the Engineer Department, that dumps the entire load to the side of the track, and a flat stone car used for the transportation of stone in construction. This latter car is similar to the Gondola, but without sides, and having a double or stronger flooring.

The cars above mentioned comprise the equipment of the road with the exception of the Individual or Company cars that belong to parties on or adjoining the road. These are mostly built after the style of those described, with the exception of the tank cars, built for carrying petroleum in bulk. The truck used for all freight cars is the iron truck, and weighs 4,625 lbs.

ON THE STRESSES OF RIGID ARCHES AND OTHER CURVED STRUCTURES.*

By Mr. WILLIAM BELL, M. Inst. C. E.

The author, after adverting to his method of constructing a curve of equilibrium for an arch unequally loaded with continuous or discontinuous weights, or under oblique pressures, proceeded to apply it to the determination of the stresses on rigid arches and other curved structures. As the consideration of an arch of masonry was more simple than that of a rigid arch, a preliminary illustration was given by an examination of the Pont-y-tu-Prydd, an arch with small stability, with the peculiarity that its spandrels were constructed with cylindrical openings. The effect of these openings was described. To show the nature of the change of the curve of equilibrium by oblique pressure of the backing, this curve was drawn on the supposition that the backing was a perfect fluid, pressing at right angles to the back of the arch. The action of a passing load in increasing the stress upon the masonry was also examined.

The stresses of a rigid arch had hitherto been a subject of considerable difficulty, owing to the intricate nature of the mathematical analysis it was necessary to employ; and the labor of applying formulæ to trace the variation of stress from point to point was considerable. Still, before the transverse sections of arch ribs could be proportioned to the stresses coming upon them, a knowledge of this variation is indispensable. The main object of the paper was to show that the stresses at every point of an arch rib could be determined by a diagram, and that some questions, such as where the form of the rib

* A paper read before the Institution of Civil Engineers.

was neither circular nor parabolic, and when the pressure was oblique, which would be almost intractable by analysis, could be readily solved. The curve of equilibrium being the locus of the resultant of all the outward forces, the bending moment was the pressure in the direction of the curve multiplied by the perpendicular upon the tangent. The curve having been determined, the stress caused by the bending moment could be ascertained, and this, added to the uniform compression, was the total stress at any point. By shifting vertically the positions of the points of the curve at the crown and springing, the stress could be indefinitely varied, and the curve could be made to satisfy the conditions of the rigid arch of invariable span, or the rigid arch with the ends fixed. These conditions were then investigated, and gave the following results. The neutral line of the arch rib having been divided into equal parts, and the bending moments at each of these parts obtained from the curve of equilibrium, when the ends were fixed the sum of all the bending moments had to be made equal to zero; when the rib was of invariable span, the sum of the bending moments, each multiplied by the vertical ordinate of the point to which it corresponded, had to be made equal to zero; and when the ends were fixed and the rib of invariable span, the above conditions had both to be satisfied. When the section of the rib changed from point to point, each bending moment was to be divided by the moment of inertia of the cross section corresponding to it, before entering it in the summation. It was then remarked that where the curve of equilibrium touched the surface of the rib, the compressive stress was doubled, trebled, or quadrupled, according as the section was I or box-shaped, tubular, or of the form of a solid rectangle. For vertical forces only, the bending moment at any point was equal to the horizontal thrust multiplied by the length of the vertical line between the curve of the rib and the curve of equilibrium. A mathematical investigation was entered into for a circular rib, considered as a voussoir arch, or rigid arch with the ends fixed, in a similar manner to Mr. Airy's treatment of the circular rib of invariable span. It was shown that the stresses could be equally well ascertained by diagram as by mathematical investigation. When a moving load was the only force acting on an arch rib, the curve of equilibrium was two straight lines, meeting in an apex vertically above the load. As the load moved, the locus of this apex depended on the condition of the rib, as to whether it was rigid, or in the state of a voussoir arch. The action of a uniformly distributed load was then examined, and the circular rib compared with the parabolic. It was remarked that a straight or curved girder might be considered as an arch of any rise, but without horizontal thrust, and it was shown that, by drawing any curve of equilibrium for the weights, continuous or discontinuous, acting on the girder, considering it as an arch, the stress at any point was the horizontal thrust multiplied by the vertical ordinate. The action of oblique forces was then entered into, and the case of the curved gates of the Victoria Docks was examined. The stresses on the elliptical caissons used in the foundation of the Thames Embankment were next ascertained by construction. It appears that when the eccentricity of an ellipse under normal pressure was small, the curve of equilibrium was nearly a circle, whose radius was the mean between the length of the major and minor semi-axes of the ellipse; and that if a boiler, which was an arch in tension instead of in compression, were not truly cylindrical, there would be considerable transverse in addition to the tangential stress, and if the deviation from an exact circle were greatest at the riveted joints, the stress would be greatest at the weakest parts. It was then remarked, that at an ordinary lap joint, or at a part where the deviation of form amounted only to half the thickness of the plating, the stress at the surface of the iron was four times that due to the uniform pressure of the steam. This result, which showed how greatly a boiler might be weakened by an imperfection of form too slight to be detected by the eye, was not, in the author's opinion, generally known. There could be little doubt that incorrectness of form, the evidence of which was destroyed when a boiler exploded, was one of the chief causes, and hitherto an unsuspected cause, of many of the boiler explosions which occurred from time to time throughout the country. The last example chosen was the somewhat complex case of the roof of the St. Pancras Station, Midland Railway. The form of

the rib differed from the circle and parabola, the section varied to some extent near the springing, and as the action of the wind on the roof was considered, the question was also one of oblique forces. The curves of equilibrium for the roof, acted on only by its own weight, were first drawn. For the actual condition of the rib, namely, that of a rigid arch with the ends fixed, the curve was contained everywhere within the depth of the rib. For a pressure of wind of 40 lbs. per sq. ft., the curve showed two maximum stresses of 4.08 tons and 4.14 tons per sq. in. The arch rib had been treated as of invariable span, but real or virtual alterations of span might be caused by changes of temperature, a yielding of the abutments, and the compressibility of the arch rib itself. It became then an important practical question to determine, for wrought-iron arches, how much the stresses might be altered by a small alteration of the span. The method of ascertaining this generally was then described, and it was found that a wrought-iron rib of 200 ft. span, 20 ft. rise, of an I or box-shaped section, and loaded uniformly, might have the stress at the crown increased from 4 tons to 6¼ tons per sq. in. This would happen if the abutments each yielded ½ in. under the thrust, and the temperature were reduced 60 deg. below that at which the parts of the rib were put together. This result included the stress caused by the compressibility of the iron.

In order to draw the elastic curve of the rib, it was then shown how to find the displacements of the different points, by change of temperature, compressibility of the metal, and action of the bending moment. The deflection of the crown was the alteration of the rise of the rib as found by this process. Applying it to the case of the rib of the St. Pancras Station roof, the deflection of the crown was found to be 2 in., while observation had given from $\frac{3}{16}$ to ¼ in., so that the agreement of calculation with observation was very close. The author proposed to measure stresses by the direct observation of the extension or compression of a small length of the material of a structure. For a stress of 1-5th ton per sq. in., the extension of a length of 50 in. of wrought iron was $\frac{1}{1000}$ of an inch, which if magnified 50 times, would be read as $\frac{1}{20}$ of an inch by the eye. During the testing of a structure, two microscopes, magnifying 50 diameters, with scales in their eye pieces, fixed about 50 in. apart, would measure stresses of 1-5th of a ton per sq. in. in the most direct manner, and the stresses could be measured at the critical point of a structure.

The author thought that this method of observation might even be useful in another way, if, as was probable, inferior kinds of wrought iron approached to cast iron in the scale of their extensibility under moderate stresses. By taking an observation where the stress could be accurately determined by calculation, the quality of the iron which had been used in a structure might be ascertained.

THE PUBLIC WORKS OF PARIS.

From "Engineering."

At one time the Paris pavement was uniformly composed of setts measuring $9\frac{1}{16}$ in. on each side, and costing 6d. a piece; but these setts under the action of a heavy traffic became smooth and rounded, affording a bad foothold. Smaller setts were then substituted giving a more even surface; the dimensions of these are $3\frac{15}{16}$ in. by 6¼ in. and 6¼ in. deep, and they cost from £10 15s. to £13 per 1,000. This new paving varies in cost from 8s. 8d. to 13s. per yard, according to the quality of the material.

The paved surface of the Paris streets is equal to 6,077,300 sq. yards, of which 180,360 yards are taken up every year; the remaining 5,896,940 yards are maintained by 82 brigades of 5 workmen each, costing annually £21,760, or about .86 penny per yard.

The area of the metalled roads will be reduced during 1872 to about 2,000,000 sq. yards, and the expense for maintenance allotted in the budget for the coming year is £131,640. A staff of 1,105 laborers is devoted to this work, and it is found better to re-make the roads entirely than to patch them. For some years past steam road rolling has been introduced. The contractor for this work

is paid at the rate of 7d. per ton per mile run by the engine during the day, and a slightly elevated rate for night work. The watering arrangements preserve the surface of the roads. Every 5 or 6 days water is poured over in abundance, succeeded by a thorough hand or machine sweeping. The mechanical brushers with one horse cost £36, and sweep 5,970 yards per hour, equal to the work of 10 men. The materials employed for the roads are :

	£.	s.	d.	
Flint, costing	0	7	0	per cubic yard.
Compact limestone	0	19	2	" "
Porphyry from Voutré .	1	9	3	" "

The asphalt roads are composed of a compact formation of béton 4 in. thick, dressed according to the ultimate curve of the road. This formation is covered with a layer in mortar, and at the end of 4 or 5 days, when the whole has acquired the necessary degree of hardness, the application of the asphalt is proceeded with.

The raw material comes from the mines of Seyssel and of Pyrimont in the valley of the Rhone. It is a limestone impregnated with 10 or 12 per cent. of bitumen. This rock is reduced to powder and is heated in a suitable apparatus to a temperature of 150 deg. It is then loaded into carts and brought on the ground, where it is spread over the béton in layers 1½ in. or 2 in. thick, then it is well beaten down with rammers or iron rollers until it resolves itself, as it were, into the original rock. This class of road—noiseless, clean, and agreeable—presents nevertheless the serious inconvenience of easily becoming slippery and dangerous to the horses. Special care has, therefore, to be taken in washing the asphalt, and covering it with sprinkled sand, of which supplies are deposited in receptacles under the footpaths.

The maintenance of these asphalt roads includes the relaying once every 10 years, and costs at the rate of 8.3d. per square yard per annum. There are altogether 287,000 square yards ofsuch roads, and 37,000 yards laid in the metalled roads.

The foot paths and alleys are of granite or of asphalt. The granite walks cost 15s. 9d. per yard, and the cost for repair is only about .88d. per yard per annum. The asphalt sidewalks cost 3.82s. and the maintenance about 3d. per yard. The local proprietors defray in part the cost of laying down the sidewalks, and the city provides £40,000 per annum for their maintenance.

The cleaning of the public streets costs yearly £162,800, divided as follows : the purchase and maintenance of material, the staff of workmen, watering, and taking away mud and debris. Tools, such as shovels, picks, brooms, watering apparatus ; and the disinfectants, such as sulphate of iron, chloride of lime, etc., are centralized in a general depot. The annual cost is £600.

The labor of sweeping and cleaning the streets is apportioned as follows : the householders and local proprietors keep clean about one-half of the whole area, the municipal authorities, at the cost of the local proprietors, clean one-third, and one-sixth is looked after by the city government at its own cost. The average cost is about 1.67d. per square yard per annum. Connected with this service are 41 workshops of 31 workmen, and 70 workshops of 17 workmen.

The watering is done from carts or by articulated apparatus connected with a hydrant in the pavement. This second system, which is only half as costly as the first, has been generalized and operates over a surface of 1,275,700 square yards at an expense of about .005d. per yard.

The mud and general debris are lifted by contractors or the land cultivators in the environs of Paris, who employ this matter as manure. At one time the sale of the refuse brought in a considerable sum to the city, but of late years this has not been the case, and while there are a large number of collectors who pay nothing, there are others whom the municipality keep in employment. The Government of the 4th September, by a decree dated the 11th September, 1870, prohibited all collectors of manure in the streets of Paris, and compelled the inhabitants to carry direct to the carts the refuse to be taken away. This decree, which brought about a great improvement from a sanitary point of view, should also reduce considerably the cost of cleaning the streets.

It is now proposed that the municipal council should institute a commission to study this question, and at the same time

that of carrying away the sewage matter and the utilization of sewage waters.

After the service of roads in the Paris administration comes that of works. This includes all the works which are executed in the public streets above the level of the roads and footpaths, the promenades and plantations, seats, columns, public announcements, kiosks, cabstands, and offices, lamps, shop fronts, the chairs and tables of cafés, etc. This service is divided into four distinct parts :

1. Promenade and plantations.
2. Lighting.
3. The concessions of the streets.
4. Public vehicles.

The growth and management of the trees in the Boulevards and avenues of Paris are matters of no small difficulty. It is necessary that they should have a good soil and a perfect drainage, that they should be preserved from damage by the public, and the deleterious effects of the gas lighting. By preference plane and chestnut trees are chosen, for they grow rapidly, give good shadow, have a beautiful appearance, and are not affected by the insects. There are to-day 102,254 trees in the Paris avenues. The cost of maintaining the trees and public seats is £7,600 per annum. As to the promenades the plan adopted was to make four grand promenades at the four cardinal points, namely, the Bois de Boulogne, the park of Buttes-Chaumont, the Bois Vincennes, and the Park de Montsouris ; afterwards to develop or to form a garden or a square in each of the 20 arrondissements of Paris.

This programme, now executed, gives to the population, besides the four great promenades, a total of 27 enclosures, covered with vegetation, and presenting a surface of at least 147 acres. The expenses for maintaining these promenades amount to £14,000, besides the cost of the plants furnished from gardens at Muette, near Passy.

The outlay incurred for the Bois de Bologne has exceeded £640,000, and £227,800 for the Bois de Vincennes. To supply the great quantity of shrubs and flowers required in the creation and maintenance of the promenades, the administration has formed vast horticultural establishments. The most important of them is the Garden of Muette, comprising an orangery, and nursery greenhouses, collectively covering an area of 73,820 sq. ft., 53,750 sq. ft. of hot beds, various buildings occupying 85,600 sq. ft., and gardens for outdoor plants. The establishment cost £16,000. There are employed on it 88 workmen, and 3,000,000 plants per annum are produced there at an average cost of .12d. each. The city possesses, besides, three establishments for raising the required trees and shrubs.

It is proposed in 1872 to reduce from £87,850 to £59,360, the outlay of the plantations and promenades. But very heavy expenses will have to be incurred, and much time must elapse before the traces of the damage done during the war and the insurrection are effaced.

STRAINS ON STRAIGHT GIRDERS AND TRUSSES.

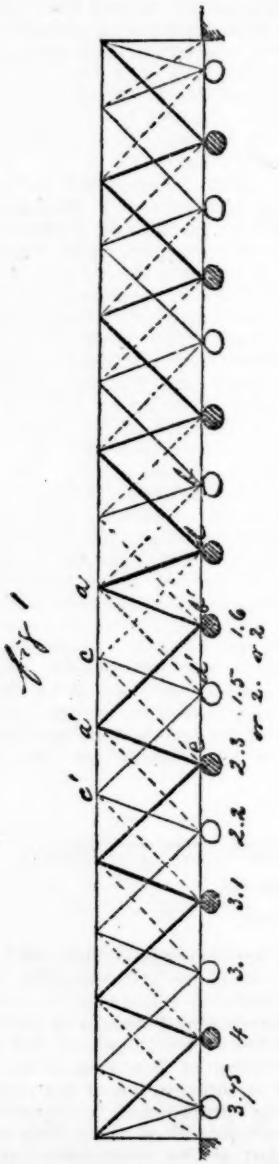
Written for Van Nostrand's Magazine.

(Continued from January Number.)

The Post truss (Fig. 1) is a compound truss of two triangular systems, the braces having a run of half a panel, and the ties, of one and a half. The weights on the ties and braces under a uniform load are determined as for the other trusses, and the horizontal strains through the chords obtained as in other cases, by multiplication of the vertical strains by the tangent of the inclined members. In the present case, the tangent of the ties = 1, and that of the braces, 0.33. The strains and horizontal increments, in loaded-panel weights are shown in the half truss, Fig. 2.

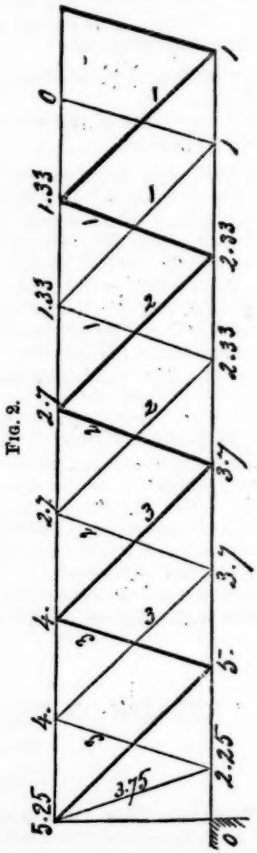
In summing the series to obtain the maximum vertical strains on the ties and braces from the rolling load, the peculiar construction of this truss at the centre, causes an interruption of the regular decreasing progression. Supposing the panel weights W′ of the rolling load concentrated at the lower apices, as in Fig. 1, we have for the coefficients of W′ in the light-lined system, (13.5 + 11.5 + 9.5 +

$6.5+4.5+2.5)\frac{W'}{16}+(15.5+0.5)\frac{W'}{16}=$ 3.75 W′, and so on for the rest, as shown



in the figure. For the heavy-lined system, we have, $(14.5+12.5+10.5+8.5+7.5+5.5+3.5+1.5)\frac{W'}{16}=4$ W′, and so on as in the figure.

Another peculiarity of this truss is that the counter-braces connect the two systems. This renders a nice calculation extremely difficult, but it is believed that the following general considerations are correct and lead to safe results.

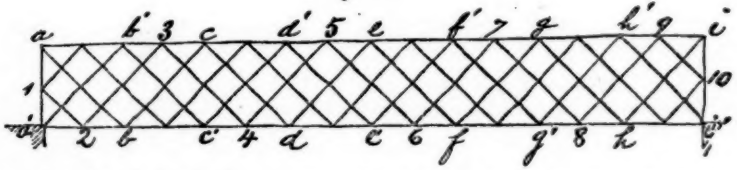


All weights and dimensions being assumed the same as for the other trusses, the counterbraces sustaining a shearing strain are *a b*, *c d*, and their symmetricals. Of these, the former sustains, vertically, 1.5 W′, and the latter, 2 W′.* When half

* Excepting for the strain on the first tie, the weight on the first and last apexes has been taken $=W'$ instead of $\frac{1}{2}W'$, the difference for all other cases being but slight.

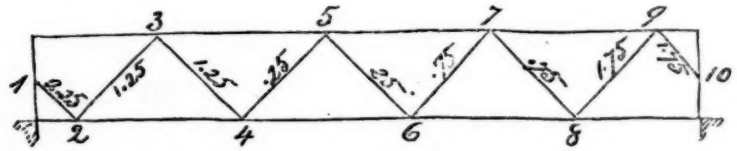
of the truss is covered by the rolling load, and the tie $a'\ b'$ is therefore under a vertical strain of $(7.5 + 5.5 + 3.5 + 1.5)\ \frac{W'}{16} = 1.1\ W'$, it is conceivable that the counterbrace $a\ b$ may transmit to it in addition through $a\ b'$, the whole of that portion of the strain which the said counterbrace receives from the other, or light-lined system. This equals $0.9\ W'$, making the whole possible vertical strain on $a'\ b' = 2\ W'$. The two panel weights on $c\ d$

Fig. 3



are transferred to $c'\ d'$, which must therefore be strong enough to bear the additional half panel weight. If the truss be loaded from e to the right abutment, the weight of 2 panels on $c\ d'$ undergoes a diminution of $6.5\ \frac{W'}{16} = 0.4\ W'$, from the effect of the tensile strain upon it from

Fig. 4.

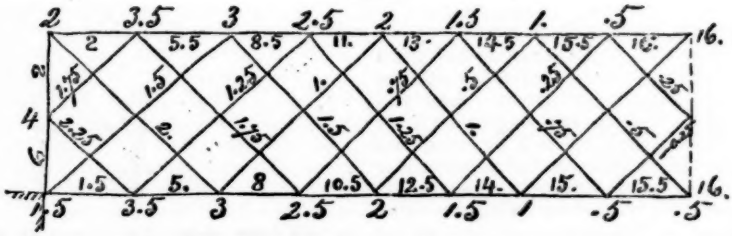


the weight at d', and therefore the strains upon the rest of the ties are sufficiently provided for by the previous calculations.

A lattice truss containing four systems of right-angled trussing requires also a rather complicated calculation.

In the truss shown in Fig. 3, let W = permanent bridge load, and W′ the rolling load, on each lower apex. In order to calculate the strains on the flanges, we must ascertain the vertical strains on the ties as braces when the truss is completely

Fig. 5.



covered with the rolling load. The weights borne by the ties and braces of the systems a, b, c, d, e, f, g, h, i, and a', b', c', etc., are easily obtained, for the weights on their apexes are symmetric in relation to the centre of the truss. Those at the apices of the two other systems are not symmetric, and the effect of each weight must be taken separately, and the total effect for each member deduced. Let us consider the system 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10, Fig. 4.

We have already seen that if a truss be loaded from a certain tie to the farther abutment, that the strain on that tie is diminished by placing weights upon the unloaded segment. This is because these last in transmitting a certain portion of their weights to the farther abutment, produce a compressive strain in the tie which must be deducted to find the net tensile strain upon it. This principle established, it is easy to calculate the strains on the members of the system in question.

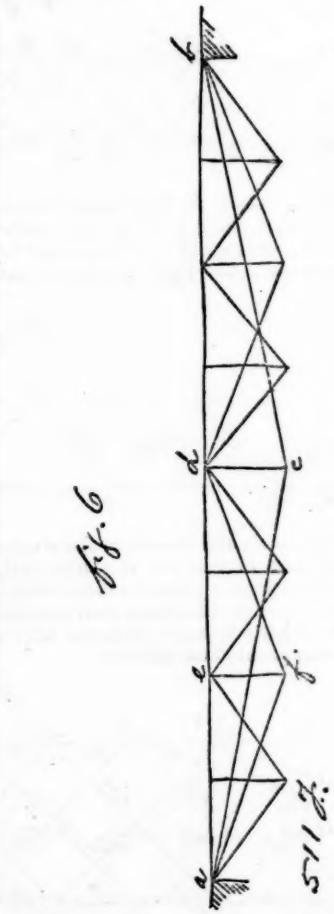
The tensile strain on 1, 2 is found by taking the combined strains of the weights on 2, 4, 6, and 8, which add up

$$\frac{36}{16}(W + W') = 2.25(W + W').$$

The tensile strain on 3, 4 and the compressive strain on 2, 3 from the weights 4, 6, 8, amount to $\frac{21}{16}(W + W')$. But the weight at 2 exercises a directly contrary strain on these members of $\frac{1}{16}(W + W')$ leaving a net strain of $1.25(W + W')$. The strains tensile and compressive on 5, 6 and 4, 5 from the weights 6 and 8, give $\frac{10}{16}(W + W)$; but from this must be deducted $\frac{6}{16}(W + W')$ from the weights 2 and 4, leaving $0.25(W + W')$ In like manner we get the proper coefficients of $(W + W')$ for the other members, as shown in the figure, and we have then all the elements necessary for the diagram of vertical and horizonal coefficients shown in Fig. 5.

The maximum strains on the ties and braces and the amount of counterbracing against the shearing strain, are determined as for the other trusses.

This example is the same as that given by Mr. Stoney in his treatise on strains, Vol. I., p. 105, except that we have considered the rolling load as passing over the bottom chord. It will be seen that the results arrived at differ materially from those given by Mr. Stoney in his diagram. This is owing to his incorrect allotment of the permanent strains on the two unsymmetrically loaded systems. That Mr. Stoney's results are incorrect is readily seen by comparing the diagram for uniform strains with the table on page 106. By the diagram, the strain on diagonal 3 when the bridge is uniformly loaded, equals 2 panel weights, while by the table, the maximum strain on this member is given correctly, as 1.75 panel weights. It is evident that this diagonal, in Mr. Stoney's example, is under the same strain whether the truss is entirely covered or only from the further abutment to apex 3, for the weights 1 and 2



do not bear upon the system of which diagonal 3 forms a part, at all, and therefore their presence or absence cannot affect it.

The Fink truss, shown in Fig. 6, differs from all those we have already considered, being in fact a series of indepen-

dent trussed beams. It is best suited for undergrade bridges. Maximum strains of all kinds occur when the whole bridge is covered with the rolling load. When so loaded, the horizontal strain throughout $a\,b = \frac{W\,L}{8\,D}$, W representing total load, both fixed and rolling, and the strain on the ties $a\,c$, $c\,b$, is to this as the length of $a\,c$ is to that of $a\,d$. Compression on $d\,c = \frac{W}{2}$. Strain on $a\,f$, $f\,d = \frac{W\,L}{16\,D} \times \frac{a\,f}{a\,e}$. Compression on $e\,f\,\frac{W}{4}$. Strains on the other sub-trusses are calculated in a similar manner.

SUBMARINE BOATS.

From "The Engineer."

Just now the torpedo is attracting considerable notice as a new engine of war. To us, islanders, it may, perhaps, almost prove the weapon of the future, at least, if the supremacy of the sea, our present boast, be ever threatened. It is mainly as an instrument of defence that we at present regard torpedoes, but they may also be used—as indeed, they have been—for offensive purposes. To this end, a submarine boat, a boat that can be submerged and work below the water as well as above it, is required. The project is at present almost chimerical, yet, perhaps, it may be not altogether without interest to trace the history of the invention.

Many more attempts have been made to attain it than is generally supposed. Of course, the idea of a boat to work below water is a very old one. Roger Bacon, who lived in the 13th century, mentions submarine vessels amongst the other marvels he enumerates. "Moreover," he says, "instruments may be made wherewith men may walk in the bottom of the sea or river without bodily danger, which Alexander the Great used, to the end that he might behold the secrets of the seas, as the Ettrick philosopher reputeth, and these have been made, not merely in times past, but even in our days." Again, in another place, our author speaks more definitely on the subject: "We have seen and used in London a warlike machine, driven by internal machinery, either on land or water. Succeeding years have shown us a vessel which, being almost wholly submerged, would run through the water against waves and wind, with a speed greater than that attained by '*Celonibus Londinensibus expeditissimis*' (the fastest London pinnaces—Facciolati)."

These accounts, however, are rather mythical, and the first true submarine vessel we know to have existed was one which Cornelius Van Drebbel tried upon the Thames, by command of James I. This was moved by 12 rowers, and according to Leibnitz, went for some distance under the water. Whether it received external air for respiration the same author does not know, but from other sources we learn that the vitiated air was purified, or said to be purified, by an artificial liquid invented by Pierre Van Drebbel, the son-in-law of Cornelius. This liquid was sprinkled about, and the air thus again became suitable for respiration. Bishop Wilkins, in his "Mathematical Magic," speaks favorably of the invention. In 1692 Papin wrote to Leibnitz on the subject of a machine, which seems to have been a simple form of steam engine for moving ships. The correspondence which ensued is preserved in the Great Seal Patent Office, but has never been published; in it Papin speaks of a submarine boat invented by himself. It was to be moved by oars at the side, and could be caused to rise or sink by pumping air into or out of internal vases. It had a mercurial gauge, was steered by a rudder, and lighted by glass windows; air for respiration could be pumped in through a tube, by "a Hessian pump," that is to say, a rotary flyer with vanes; the vitiated air escaped by another tube, while a third enabled the diver to attack an enemy's ship.

Probably these and similar inventions, though applicable to warlike purposes, were chiefly intended to fulfil the same end as the diving bell, the principle of which was known (it is first mentioned by John Taisnier, who was born at Hainault, in 1509), though, of course, it was not yet brought to perfection by aid of

the numerous mechanical appliances now in use. About the same time, or a few years earlier than the date of Papin's machine, J. A. Borelli invented a sort of diving apparatus. This, indeed, was not a boat, but more nearly resembled the diving dresses of the present day; still it deserves notice as a curiosity. It consisted of a large metal vessel filled with air, which could enclose a man's head and be secured round his neck. About the wearer's waist was a cylinder holding air, furnished with a piston to enable the diver to raise or lower himself. To the feet of the diver webbed pins with hooks at their ends were to be fastened, so that he could swim or crawl crab-like along the ground. No mention is made of any weight to be attached to the diver's body, but certainly he must have required a good deal to carry down so much air with him. More nearly connected with our subject is a *navis urinatoria*, described by the same inventor—a covered vessel with bags open to the exterior water, by pressing which the water would be squeezed out and the boat lightened, so that it might ascend. This was certainly the most primitive form of force pump imaginable, and one by no means unlikely to work a good deal better in theory than in practice. However, Borelli is not the only inventor whose discoveries are open to the same objection. To move this boat, oars were to protrude through air-tight holes, or there might be "one flexible and elastic oar with a broad blade placed on the vessel's stern, by the vibration of which a ship could be propelled forward, as fishes are by their tails." (Borelli, "*De Motu Animalium*," Rome, 1691.) In his "*Acta Eruditorum*," published in 1683, J. Bernouilli took the trouble to prove that Borelli's machine was impracticable, as indeed it apparently was. Ten years later, in 1693, an engine of apparently similar nature was patented by John Stapleton, but hardly any description of it is preserved. The heading of the patent tells us that it was a "new and extraordinary engine of copper, iron, or other metall, with glasses for light, and joynts soe contrived as to permit a person enclosed in it to walke and move freely with it under water, and yet so closely covered over with leather as sufficiently to defend him from all the jumps thereof." There was also an engine that would "swim upon the water in the most violent storms," and sink to the bottom and rise again when required. Besides these two machines—the former of which was apparently a sort of diving-dress, while the latter seems to have been a true submarine boat—the patent included a method of "defecating" or purifying air after breathing. This was to be used if the supply of fresh air was cut off by any means. One year before this (1692), John Williams invented an engine "for the conveyance of four men 15 fathom and more under water in the sea, whereby they may work 12 hours and more without any danger, which said engine will be of great use and advantage for the taking up of wrecks and shippes that have been and shall be lost in the sea." No description of the machine is given, but—a thing very uncommon in the case of old patents—there is a drawing of it still preserved in the Rolls Chapel. By this it appears to have been merely a long water-tight cylinder, closed at the bottom, down which men could pass. At its lower end, which of course rested on the bottom, were windows and holes fitted with water-tight sleeves, through which men could pass their arms so as to take hold of exterior objects. Doubtless this engine should not be classed among submarine boats, since it was only a bad substitute for a diving-bell, resembling a machine described by Vegetius, in 1532. This latter consisted merely of a cup which fitted the diver's head, and had a long leather pipe attached to it, the end of which reached to the surface of the water.

A boat is also mentioned as having been made during this century by one Day, which could move below the surface; but the inventor was drowned in his second experiment, so that little or nothing is known of his machine. The next submarine vessel we hear of was of French origin. In 1722 some experiments were made by Dionis of Bordeaux, an account of which is given in the "Journal Encyclopedique" of August 1, 1772. From this we learn that his machine carried 10 persons a distance of 5 leagues below water in the Bay of Biscay, and that it remained below 4½ hours, without having its supply of air renewed.

Such were, in brief, the earliest attempts at submarine navigation of which

we have any record remaining. They are, of course, more interesting in an antiquarian point of view than in any other, especially as so little description of any of them has been preserved, that we can scarcely do more than make out the principles upon which they were constructed, and can certainly derive no useful information from any one of them. Certainly the easiest way of treating such accounts is to put them all aside as forming a set of idle tales; but this is not a very philosophical style of treatment, and probably there is more truth in them than we are altogether ready to believe. At all events, there is nothing in the results said to be achieved by any of the machines, which is absolutely impossible, as later experience has amply shown.

So much, then, for the earlier inventions, that form what we may call the legendary or mythical age of the science. Those we now come to are much more fully recorded, and belong, in fact, to our own mechanical age. The invention of torpedoes gave a great impulse to the endeavors to make a vessel which should carry them; hence the next person we come to is remarkable for having been at once the inventor of these infernal machines and the first contriver of a submarine vessel that we possess a full and accurate description of. David Bushnell, of Connecticut, seems undoubtedly to have been the originator of the notion of blowing up a ship by an explosive engine applied to her hull. The stationary torpedo he does not appear to have employed, but only to have conceived the plan—not even yet fully perfected—of attaching a torpedo to an enemy's ship. Hence his submarine boat. Of this we have ample description. A MS. account of it is preserved in the Patent-office Library in London, and there is besides a paper originally read by Captain Bushnell himself, before the American Philosophical Society, and republished in the "Repertory of Arts," vol. xv., p. 385, which gives a full account of it. From these descriptions we gather that the boat was tortoise-shaped, very strongly built of two elliptical plates of iron bolted together at the edges, and affording in the hollow between them sufficient space for a single person. At the bottom it was heavily loaded with lead to insure stability, but it could also take in ballast for the same purpose. Besides the operator, air sufficient to support him for 30 min. could be contained in the inside. At the top was an opening with an air-tight door for entrance, at the bottom another door or valve through which water could be admitted when it was desired to descend, while a couple of force pumps served to eject the water when ascent was wished for. There were also two ventilating tubes on the top of the boat, which closed of themselves under water, and opened in the air. For motion there were two screw-shaped oars —one vertical, the other horizontal. They could be turned either by the hands or the feet, and are remarkable as being an early instance of the use of the screw-propeller. Part of the ballast was fixed so that it could be suddenly let down about 40 ft. or 50 ft. by a rope, and by this means the boat be permitted to rise suddenly in case of accident. There was no light, except such as might be admitted through the "dead-eyes" above, so the compass and the water-gauge, by which the depth of immersion could be ascertained, were rubbed with phosphorus to render them visible. Such was the boat in its principal parts as relating to its powers for navigation; but scarcely less important, considering the end it had to serve, was the arrangement for attaching and exploding a torpedo. In the fore part of the boat was a tube through which passed a screw that could be driven into the wooden bottom of a vessel and left there. Attached to the screw by a line was a powder magazine, which was cast off at the same time as the screw was detached. The screw being driven in, the infernal machine floated up against the side of a vessel, and was then exploded at a certain time by a clock-work apparatus that was started by the casting off the machine. This was the whole contrivance, and a most ingenious one it was. It was completed in 1775, with the object of being used in the War of Independence. The first experiments were upon hogsheads loaded with stones, and these being successful, the inventor was encouraged to make an attempt upon the Eagle, a 64-gun ship belonging to the English. The boat was sent out under the direction of a man named Ezra Lee, who succeeded in getting under the vessel; but when attempting to fix the screw into its hull he struck a bar of iron. Trying to find

another place, he lost the ship and was obliged to rise to the surface to look about him. Daylight was then coming on, so he deemed it advisable to return, *re infecta*. On his voyage home he found the torpedo impeded the boat in the heavy sea, so he cast it off, thus setting the clockwork in motion, and at the appointed time it blew up. A detailed account of the adventure, taken down from Ezra Lee's own lips, is given in "Silliman's Journal" for April, 1820.

Another attempt upon the Cerberus frigate, in 1777, was hardly more successful. Bushnell tried to tow a torpedo against her side by means of a long line. This line was discovered by the crew of a schooner lying astern of the frigate and hauled in. While they were examining the torpedo, not knowing what it was, it blew up, and destroyed the schooner, killing three of the four men on board. Two or three months later in the same year Bushnell filled a number of kegs with gunpowder, and, after fitting them with percussion fuses, tried to float them down the Delaware agains the English shipping. Unfortunately for the success of the enterprise, the kegs were frozen up for some time, and at last drifted down in the daytime. The crew of a barge attempted to take one up, when it exploded and killed four of them. Upon this a terrible commotion was aroused, no one knowing the cause of the explosion. The soldiers turned out, the populace rushed upon the quays, and everywhere was the greatest confusion, until at last the origin of the sudden attack was discovered. Upon this the fleet opened fire upon the kegs, and continued until every floating object had disappeared. Naturally enough, this vigorous warfare upon an inanimate foe gave great amusement to the Americans, and the "Battle of the Kegs" was celebrated in not a few mock-heroics, amongst others in a poem by the father of the writer of "Hail, Columbia."

At last Bushnell, disheartened at the ill-fortune of his endeavors, gave them up and left America. Afterwards returning, he changed his name, and lived for some time in retirement in Georgia. At his death his real name became known, and his possessions were inherited by his proper heirs, a descendant of whom is now resident in New York.

Of the value of his invention we have direct testimony in a letter from Washington to Jefferson, written September 26th, 1785. In this General Washington speaks of Bushnell as a man of great mechanical genius, though he did not believe in the practicability of his schemes. There was no doubt, the letter said, that Bushnell had a machine capable of conveying him to any depth, by aid of which he could fasten an infernal machine to the hull of a ship. The objection which General Washington saw was, that there were too many difficulties to be overcome, and that the chances of success were too small. "I thought," he says, "and still think, that it was an effort of genius, but that there were too many things to be combined to expect much from the issue, against an enemy who are always upon guard." This was true, and still remains so; for, though the opinion was passed upon one of the earliest inventions of its kind, no means have yet been discovered of accomplishing the same object with certainty and security. Bushnell, however, did this much: he showed that the offensive use of torpedoes by means of a diving-boat was possible, and he left it for future engineers to perfect the system he had originated.

It is naturally only during war that we hear of new weapons being contrived. Hence we have to pass over twenty years before coming to another boat of the sort we are discussing. Fulton, when engaged upon his steamboat, went to France (1796), and when there tried to revive a project of his for a machine which could move under water. By its aid, "he hoped to deliver France and the whole world from British tyranny and oppression" (Colden's "Memoir of Fulton," p. 15). His first experiment was made on the Seine. He attempted to impart motion to kegs of gunpowder under the water, and then explode them; but this scheme, like all others for contriving an automatic torpedo, failed, the Minister of Marine pronouncing it impracticable, as did also the Batavian Directory, to whom Fulton afterwards applied. At last Bonaparte, always ready to favor any scheme which gave him a chance of overcoming the English upon their own element, gave him money, with which he continued his experiments at Havre and Brest (1801). He then so far perfected his Nautilus—such was the name he gave his boat—that he could immerse it 25 ft. under water, and remain there an

hour. During this time the crew were in darkness, or at least they had only such light as a window in the bows of the boat could admit, since candles or other lighting apparatus would consume too much air. The boat could sail on the surface, but not well; and thus belonged to the class of diving boats, or *plongeurs*—boats intended only for occasional and temporary immersion. It took about 2 min. to prepare her for immersion. On one occasion he plunged to some depth, moved about 500 yards, came to the surface, again plunged, and returned to the spot from which he had started. On another occasion he remained below water for 4 hours and 20 min. without inconvenience, having taken down a globe of about a foot cubic capacity, filled with compressed air. He succeeded in demolishing an old brig in Brest harbor, and attempted to blow up an English man-of-war; but when he was on the point of attaching his torpedo the ship moved away, and he was unable to find her again.

Fulton does not seem to have carried his experiments beyond this to France; but in 1805 he was in England, where, in order that his identity might not be known, he adopted the name of Francis. Of his experiments here he has left us an account in a curious and rather scarce work called "Torpedo War," published in New York in 1810. He tells us how he got permission to make attempts upon the Dorothea, a strong-built Dutch brig, which was moored for the purpose off Walmer Castle. In this case he did not use his submarine boat, but towed 2 torpedoes against the ship by means of a line 70 ft. long stretched between 2 boats. After a day or two's practice with blind torpedoes, he succeeded in towing 2 that were filled with powder against the vessel's sides, where they exploded and blew the ship to pieces. "In 20 sec.," says Fulton triumphantly, "nothing was seen of her but floating fragments." It was rather curious that among the spectators was an officer who declared, 20 min. before the explosion, that if a torpedo were placed under his cabin when he was at dinner he should feel little concern for the consequences. Of his unsuccessful attempt against the French fleet, made shortly before his experiment on the Dorothea, Fulton makes no mention in his book. In this case the machine exploded prematurely, and the gunboat attacked was not injured. His next experiment was in America, in New York harbor (1807). Here the locks by which the torpedoes were to have been exploded turned downwards, so that the powder fell out of them and they missed fire. On a second attempt the torpedo exploded at the wrong time, but on a third trial the ship was blown up. From the evident uncertainty of the machines they naturally came to be regarded with no great favor; still we must remember that the means at Fulton's command were very imperfect; his row-boats and torpedoes, exploded by flint-locks, might hardly have been expected to accomplish more. Owing to the ill-success of his designs, Fulton seems to have given up his scheme of a submarine vessel, as indeed he soon after did all his attempts at making torpedoes, and devoted himself to his steamboat. During the war with America torpedo-boats of different sorts seem to have been used, but with no great success. "Nile's Register" (American) speaks of one which escaped pursuit by diving like a porpoise.

As with many other inventions, the advocates of the new schemes were very sanguine as to their powers, and hoped, by means of the new engines, to destroy or render useless all the fleets of the world, and thus render the seas peaceful. Fulton, writing to one William Brent, said: "If successful, their benefits to America will be immense, for I still assert, and every reflection confirms my opinion, that these submarine mines must go to the annihilation of military navies, and consequently produce the liberty of the seas, relieve us of all the trouble and expense of our foreign negotiations, and turn the whole genius and resources of our people to useful arts." An expression of Lord St. Vincent shows the same feeling. After hearing from Fulton a full account of his machines, he declared that "Pitt was the greatest fool that ever existed to encourage a mode of warfare which they who commanded the seas did not want, and which, if successful, would deprive them of it." Whether we still have command of the seas remains to be seen; at least we may hope that the question will not have to be solved just yet awhile. At all events, we are hardly strong enough to make it worth our while to despise the use of torpedoes—weapons

adapted, beyond all others, to coast defence. As to the inhumanity of the machines—a question upon which the minds of their earliest opponents were greatly exercised—of course the progress of civilization during the past 2 years has quite settled that question. Indeed, all warlike inventions from gunpowder unwards have, each in their turn, been condemned after the same fashion.

From the time of Fulton to the breaking out of the American Civil War no submarine vessels seem to have been constructed. Several patents, indeed, were taken out in England for inventions of this sort, but none of them seem to have been much experimented with, or to have had much success. In 1805 John Schmidt and Robert Dickinson invented a sort of diving machine, which was to be moved by oars working at its lower edge. In it the vitiated air was to be free from carbonic acid by providing for its absorption by caustic alkali. This is noticeable as being apparently the first time this means was used for the purpose. As yet nobody seems to have succeeded in really purifying air by caustic alkali, but there seems no reason why it should not ultimately be done. The difficulty is to separate the impure air from the remainder, and expose it specially to the purifying action. The next English patent connected with the subject was granted in 1854 to J. H. Johnstone, for a vessel, invented by Messrs. Payerne and Lamiral, with several compartments, some open to the water, as in a diving-bell. Propulsion was to be effected by a steam engine, whose fuel was "a chemical composition." The air was to be purified by an alkaline solution, while oxygen or condensed air might be carried, to be used as need required. The following year Casimir Deschamps and Charles Vilcocq patented a "free diving boat," to be propelled by a screw turned by the hand. Its chief peculiarity consisted in an arrangement for an electric light at the top. A "Nautilus," described in the "Journal of the Society of Arts," March 6th, 1857, as the invention of Major Lears, was not really a boat, but a sort of diving-bell, which was not suspended from above, but ascended and descended by the admission and emission of air from above through tubes. It could be moved by men walking on the bottom, and pressing against the inside, but no other means for horizontal motion were provided. A machine of the same sort was at work in Cherbourg harbor in 1855, while as far back as 1776 the Society of Arts had given a prize to Mr. Spalding, of Edinburgh, for a similar invention. In 1859 another submarine boat was invented by J. M. Masson; in it the chief features of novelty are described as consisting in the compression of the air before descent, and its increased compression by means of the generation of carbonic acid gas within inflatable india-rubber bags.

The outbreak of the American war gave great impulse to the use of torpedoes, in fact it was in the defence of the Southern coast that these weapons were first used to any real extent in war. Hence various attempts on both sides to construct a submarine boat which should be used to carry a torpedo. For this purpose two sorts of boats were used, one submarine, the other not. In spite of the difficulty of getting a small vessel close to a ship without being observed, swift steam launches on more than one occasion managed to explode a torpedo against the sides of a hostile ship, sometimes with considerable effect. The Federal ship Memphis was severely injured by one of these "Davids"—as they were called from their diminutive size—and the Ironsides damaged, but not so severely. When Charleston was taken, 9 boats, specially constructed for this purpose, were found there. They were "cigar-shaped," very low in the water, and by no means particularly safe, one of them having, it is believed, been swamped by the wave raised by the explosion of its own torpedo. They trusted to their small size to escape detection, while the same fact made them a difficult target for their opponent's guns. On the other side, the Confederate iron-clad Albemarle was sunk by Lieutenant Cushing with a steam-launch carrying a torpedo on the end of a spar. The ship was moored to a wharf with a barrier of logs round her; but Lieutenant Cushing, with the most reckless daring, actually charged the barrier, partially burst it in, and succeeded in exploding the torpedo under the quarter of the iron-clad, which immediately went to pieces.

These were the most important instances during the war of the attack and in-

jury of ships by torpedo rams which had not the power of being submerged. One instance, and one alone, there is of a ship having been destroyed by a submarine boat. The Housatonic, a Federal sloop of war, was lying outside Charlestown harbor on the night of February 17th, 1864, when the officer of the deck noticed something like a plank floating close to the ship; it came rapidly towards him, and reached the ship's side about two minutes after it was first observed; in another minute the explosion occurred, before the engines could be backed, or any preparation made to repel the tiny foe, especially as from the position of the guns it was impossible to fire at it while close under the ship's side. Immediately on the explosion the ship sank stern first, the crew, with five exceptions, saving themselves by going into the rigging. The destruction therefore of the ship was complete, but it was bought at the expense of the loss of the attacking boat, which was never again heard of. It was supposed either that she went into the hole made by the torpedo in the Housatonic, or that she was swamped by the sinking of the ship. Recent explorations by divers have shown the latter to be the case. She seems to have been a remarkably dangerous craft, for three times before, she had sunk and drowned all, or nearly all her crew, but had been on each occasion raised, till at last, her mission accomplished, she sank out at sea, to rise no more.

She was built of boiler iron, 35 ft. long, and was manned by a crew of nine men, eight of whom worked the propeller by hand, while the ninth steered. She could be submerged to any depth; in smooth water her speed was 4 knots. It was intended that she should dive under the keel of an anchored vessel, and drag a floating torpedo against her, which should explode on touching the ship's side. On this occasion, however, she seems to have adopted the plan of carrying the torpedo at her bows, as was usual with torpedo-boats. It is also noticeable that she did not approach the Housatonic below water, but was visible from the deck while nearing her. A few months later, a similar attempt was made on the U. S. steamer Memphis, but the boat was perceived fifty yards away, so the ship slipped her cable and went ahead. Owing to this movement the boat passed under the stern of the steamer, and it is supposed that the screw broke the spar on which the torpedo was fixed, for she disappeared. In appearance she was described as being like a ship's boat turned bottom upwards; she was about 25 ft. long, and painted lead color.

At an early period of the war the Government of the United States paid a Frenchman $10,000 for an invention of a submarine boat, and arranged with him to superintend the working of it. It was intended especially to blow up the Merrimac. Unfortunately, as soon as the boat was completed the Frenchman decamped, and as no one understood it she was never much tried. She was cigar-shaped, and was intended to be sunk by admitting water into a compartment and raised by its expulsion. She was to be be propelled by 16 oars, the blades of which were like a duck's foot, and collapsed during the forward stroke. To purify the air there was a vessel containing lime, and a bellows attachment for forcing the air through it. It was said that the Frenchman's plan was to emerge from the boat in a diving dress, attach a torpedo, and leave it to explode by machinery. A more perfect torpedo boat, but not a submarine one, is the Spuyten Duyvil, constructed at the end of the war, for the United States Navy. A description of this most remarkable vessel will be found in a book published in New York, by Lieut.-Commander J. S. Barnes, United States Navy, under the title of "Submarine Warfare," a work to which we also owe the account of the boat above referred to, and much information on the subject of torpedoes as used during the American wars.

In England we have not, of late years, had any notable inventions of this sort, the principle being one patented by Mr. Merrian, an American. Even in this there are not many principles of novelty. The boat is of ovoid shape, and consists of several compartments, in one of which the crew can work, while the others are to be used as reservoirs of air, to be stored up at any required pressure. The bottom is a heavy cast-iron plate; in it are several doors, one of which is inclosed within an air-tight compartment, so that it can be opened to the water, if needed, as in a diving-bell, without affecting the pressure

of the air in the other compartments. Fore and aft are heavy weights, which can be raised or lowered, to act as "suspended ballast," or even as anchors. A screw propeller is arranged on a swinging frame, so that it serves as a rudder. Forward is a bar with suitable gearing for attaching a torpedo without going out of the boat. The boat is intended to be used both for military and other purposes.

A few years before, a foreign patentee, named Rivie, took out a patent for a boat, consisting of two concentric cylinders, between which water was to be admitted. Also W. Bauer, of Munich, in 1853, invented a submarine boat, which was to be driven by a gas engine. Air was to be supplied from above by pipes. In the sides were holes fitted with water-tight sleeves (as in Williams' invention, 1692), through which the arms of the crew could be thrust, so that they might work outside. The same inventor in 1866 patented a submarine vessel capable of a certain amount of independent motion, by aid of a screw propeller, but intended to be let down by chains from a ship.

In the Paris Exhibition of 1867 a model for a submarine boat was exhibited. It was not allowed to take any sketch, and the following description is taken from an account of it given in "A Treatise on Coast Defence," by Von Scheliha (London, 1868). The model is a French one. The dimensions of the boat are:—Length, 43.3 metres; height, 3.36 metres; width, 7.5 metres. On the top is a deck. She is to be propelled by a screw, placed in the usual position. The engine is worked by compressed air, as is also a pump for emptying or filling water reservoirs at the bottom of the boat. There is an apparatus by which it was said the boat could be instantly lowered or raised to the surface. On the top of the vessel a life-boat was secured by screws. Besides the main screw, a small vertical screw above the boat is intended to assist its ascent or descent. A tube for a torpedo, to be fired by electricity, is attached. Whether any experiments have been made with this boat does not appear, and the late war has not given many opportunities for testing its use, or, possibly, we should have heard more of it.

Such, in brief, seem to have been the principal recorded instances we have of vessels of this nature. From them it will appear that the problem of submarine navigation is, at least, not insoluble, whatever may be the difficulties in the way. True, these difficulties are so great that the general opinion of engineers is in favor of torpedo-rams, which have no power of being submerged, as—with all the danger attending them—being less risky than the diving boats. Still there seems no reason why they should not eventually take their place among engines of war. Before this can be the case, the immense danger attendant on their use must be got over by their being made more perfect and sure in their working than they as yet are. As for the supply of air, the boat need only be submerged for a short time, and sufficient air for a small crew can easily be taken down in a compressed state, even without the assistance of any purifying or disinfecting agent. The use of "suspended ballast," which might be cast off instantly, if required, so that the boat would rise to the surface, would get rid of the danger arising from the slight difference between the weight of the boat and that of the bulk of water displaced, so that a very small derangement is enough to make her sink at once. True, the motive force is a difficulty. Steam is, of course, out of the question, from the great amount of air consumed, and hand power is hardly sufficient, while it involves the presence of a comparatively numerous crew. Perhaps the gas engine may supply the want, as the material for the supply of the engines is capable of being so immensely compressed that it takes up hardly any room to speak of. How the remaining chief difficulty, that of directing the boat under water to the required spot, is to be got over, it is not easy to say. This is the great problem, and though as far as we can trust the accounts of their exploits, Fulton and Bushnell accomplished it, modern engineers have not been so successful. Perhaps the most that can be hoped for is, that a boat should by night approach within a certain distance of an anchored vessel, accurately lay its course, and then dive below her, and fix a torpedo to be afterwards exploded. Percussion torpedoes must of necessity be somewhat dangerous to the boat which carries them, as well as to the ship attacked. Altogether the difficulties do not seen insuper-

able, and perhaps the next maritime war will see a flotilla of these tiny but venomous war ships. How effective they would be if they could be made safe and certain in their action, is obvious. Two or three of these insidious little vessels might destroy a whole fleet of iron-clads, whose weak point, like that of Achilles, is in the heel. True, it is said that the way iron-clads are built, in several compartments, would prevent one of them being sunk by a torpedo; but this is very doubtful, and it is much more probable that a torpedo well fixed to the hull of the finest iron-clad in the world would soon decide its fate. Besides, even the mere fact of the presence of torpedo boats has a very harassing effect upon a fleet, any one of which may suddenly, without a moment's notice, or a chance of self-defence, be blown into the air. Such considerations render it certain that the Goliaths of the sea will, in case of war, have to encounter the attacks of "Davids," such as the best of those used in the American war, or boats like the Spuyten Duyvil above referred to; whether their place will be taken by a true submarine vessel cannot as yet be said. It is at least less unlikely than is generally supposed.

GRADIENTER SURVEYING.

By H. HAUPT, C. E.

Written for Van Nostrand's Magazine.

An experimental survey has just been completed for the extension of the Shenandoah Valley Railroad, from Covington, Va., to Russelville, Tennessee, the results of which, as regards economy and rate of progress, are so extraordinary, that a brief account of the system which has been adopted may not prove uninteresting.

The number of miles surveyed was 300; the whole time in the field about 5 months; the whole cost of the survey, $1,850, of which $1,050 was for salary of the assistant in charge, leaving only $800 to cover expenses of wagon and party, including supplies and outfit.

A considerable portion of the route was through brush and laurel thickets, where rbads were cut for the ox wagon which carried supplies.

The average daily progress was 3 miles, maximum 7½ miles; but on long summer days 10 miles in open ground would be practicable.

The instrument used was Würdemann's gradienter, to which stadia wires for reading distances by means of rods had been added.

DESCRIPTION OF GRADIENTER.

The gradienter consists of a light but very powerful telescope, with attached spirit level and compass box, horizontal limb graduated from zero to 360 deg., circular spirit level attached to limb, and instead of vertical limb, a peculiar arrangement for measuring angles of elevation called a *percentage screw.*

This is the ordinary form of the gradienter as manufactured for the Coast Survey Department, but to adapt it to railroad experimental surveys, three stadia wires were added, the middle horizontal wire intersecting the vertical wire in the axis of the telescope, the other two forming spaces having the relative proportion of 1, 2, and 3.

The percentage screw is the great feature of this instrument. It is finely and accurately cut, and carries a horizontal disc of about 1½ in. in diameter, on the periphery of which are 100 subdivisions. This disc revolves in contact with a vertical graduated scale, and the parts are so calculated and adjusted, that one complete revolution of the percentage screw corresponds with one division of the scale, and each division marks 1 ft. in 100 of elevation or depression. The percentage screw subdivided this foot into 100 parts with surprising accuracy, showing great nicety of mechanical construction.

In testing the instrument at a distance of 500 ft., the elevations as determined by the percentage screw would seldom vary more than an inch from true levels; and although this would not be sufficiently accurate for canal surveys or railroad final locations, yet for experimental lines such an instrument is of great utility,

and it can be used as an ordinary level with less rapid progress where great accuracy is required.

RODS.

The rods used were of peculiar form, constructed by the writer to facilitate the reading by the assistant of levels and distances at the same time. Each rod consisted of two pieces 3 in. wide, ½ in. thick, and 10 ft. long, connected by hinges so as to shut together like the leaves of a book, and thus protect the graduation from abrasion. One side of these rods was graduated in feet, tenths and hundredths from the bottom up, and read as an ordinary levelling rod by the assistant. The other side was graduated from the top down for distances, by first measuring accurately 500 ft., and marking the space covered by the extreme wires. This space being subdivided into 5 parts, each part would represent a distance of 100 ft., and each of these spaces was again subdivided into 100 parts representing feet. The graduation was peculiar and very legible.

MODE OF USING THE GRADIENTER AND RODS.

The adjustments of the instrument are simple, but as the threads of some of the most important screws are fine and delicate, care must be taken not to strain them.

The instrument being adjusted, the first operation consists in levelling by the sensitive circular level attached to the horizontal plate. Next, to bring the zero of the percentage screw in contact with the zero of the scale, when the level attached to the telescope should also be horizontal. If it is not, the instrument is out of adjustment. Next, place the zeros of the vernier and limb in juxtaposition and clamp them. Next, turn the object end of the telescope towards the north and unscrew the needle; when the needle has settled, bring the zero of the compass arc to it by means of the tangent screw, and clamp firmly. The telescope is now in the direction of the meridian, and the verniers at zero; the needle may now be screwed up; it is not used for reading courses, but only to determine the meridian, for which purpose it is made long and sensitive. The vernier is now unclamped and the courses read from 0 deg. to 360 deg.

The observer now turns the telescope to the back rod, and, bringing the top hair to the top of the rod by means of the percentage screw, reads and records the distance and the course.

Next bring the zero of the percentage screw to the zero of the scale. If the rod can be seen, the level can be read at once; if not, the telescope must be elevated or depressed, so as to bring the middle wire against the rod. It is most convenient in practice to turn the percentage screw a given number of complete revolutions, as it renders calculation more simple. A single example will be sufficient for explanation.

Suppose the distance as recorded is 480 ft., that the level from the observer strikes below the bottom of the rod, and that the telescope has been elevated 5 turns of the percentage screw to bring the rod into view, as each turn corresponds to 1 ft. in 100, 5 turns would be 5 ft., and in a distance of 480 ft., the elevation of the line of sight would be $480 \times 5 = 24$ ft. above the level. If this line should strike the rod at a reading of 5.42, then $24 - 5.42 = 18.58$, which would represent the level of the instrument *below* the bottom of the rod, and the reading would be entered in the column of back sights 18.58.

Suppose the ground continued to descend, and the forward sight should read 30.20, the difference of level between the two stations, equal to the difference between the back and forward sights, would be $30.20 - (-18.58) = 48.78$ ft. It will be perceived that by this system *negative* rods can be read, which is not possible by the ordinary system of levelling, where, if the line of sight strikes below the rod, the instrument must be moved to a higher level. It is also possible, by means of the percentage screw, to read *positive* rods of 40 or 50 ft. with considerable accuracy, and thus avoid the short intermediate stations required in ordinary levelling.

The survey of the Shenandoah Valley extension, just completed by O. Barrett, Jr., is the first upon which this system of surveying has been used. The results, however, are very satisfactory. The cost per mile as compared with former surveys, has not been more than one-fourth, and the daily progress double. The engineer records at each setting of the instrument courses, distances, total distance, back sight, forward sight, total level, and slopes. It is not absolutely neces-

sary that a man in his party should be able to read or write, but it is convenient to have an axe man who can mark stations. One axe man and two rod men constitute the party. Each of the rod men should carry a short bill hook suspended from his belt to be used in cutting through thickets.

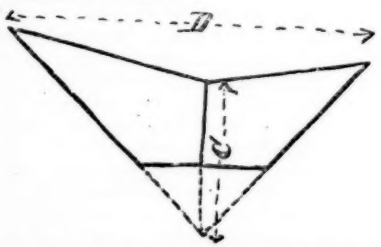
One rod could be dispensed with, but the progress in open ground is much more rapid with two.

Instead of using stakes exclusively, it is preferable, where practicable, to mark stations on trees, fences, rocks, and buildings, and to mark with paint. The measurement of distances by the stadia wires is, on broken ground, quite as accurate as ordinary chaining. And in crossing streams, marshes, or other obstructions, it has great advantages; they scarcely retard progress where measurement by chain would be impracticable.

A SIMPLE FORMULA FOR EARTHWORK.

Written for Van Nostrand's Magazine.

The computation of earthwork is generally affected by the use of tables, but the engineer not unfrequently finds himself unprovided with these, and is then obliged to go through with a great deal of tedious figuring in taking out his quantities. It is hoped that the following simple formula may be occasionally found useful in such cases.



If the side slopes were continued under the road-bed, they would meet at a certain point, which, with a given width of formation and ratio of slope, would be at a constant distance below grade, and form a continuation of the centre height, as shown in the figure. There would be also, a certain constant solid under-formation in excess of the actual quantity to be taken out, in a given section. This solid can be easily calculated, once for all, for any given road-bed and slope, and reserved as a subtractive quantity to be deducted from that obtained by computing the whole solid above and below the road-bed.

Let C = the centre height at one end of a section of 100 ft., *plus* the constant distance of the point of junction of the two side slopes under the road-bed, and D = the sum of the distances out, at the same end. C′ and D′ = the same at the other end, and P = the constant subtractive solid already mentioned.

The total end areas above and below grade are easily obtained from these data. Thus, the area at one end $= \frac{C\,D}{2}$, and at the other, $\frac{C'\,D'}{2}$. The mid area $= \frac{C''\,D''}{2}$.

The prismoidal formula gives for the cubic yards in a 100 ft. section :—

$$S = \frac{100}{6}\left(\frac{\frac{C\,D}{2} + \frac{C'\,D'}{2} + 4\,\frac{C''\,D''}{2}}{27}\right)$$

C″ and D″ are obtained by taking the arithmetical mean of C, C′ and D, D′. We have therefore,

$$S = \frac{100}{162}\left(\frac{C\,D}{2} + \frac{C'\,D'}{2} + 4\left\{\frac{\frac{(C+C')\,(D+D')}{2\quad\ 2}}{2}\right\}\right)$$

Reducing, and subtracting P, we obtain the working formula—

$$S = 0.3086\,(2\,C\,D + 2\,C'\,D' + C\,D' + C'\,D) - P$$

In ordinary calculations the first factor may be taken at 0.31. When the excavation runs out, C′ = the constant height under the grade, and D′ = the width of road-bed, the first factor $= \frac{L}{324}$, and the subtractive solid $= \frac{P\,L}{100}$.

The above calculations are of course applicable to embankments also.

Mr. John Warner has based some excellent earthwork tables upon the continuation of the side slopes below grade, with the subtraction of the "Redundant

Prism," but it is believed that the above adaptation of the prismoidal formula has never before appeared in print.

In this connection, it may be in place to give the following convenient formula for side heights:

Let C = centre height of cut or fill.
R = reading of rod at station.
R′ = " " side stake,
Then in cut, whether up or down slope,
Side height = R + C − R′.
And in fill, whether up or down slope,
Side height = R′ + C − R.

FOUR-WHEELED LOCOMOTIVES.

From "Engineering."

During the past 2 or 3 years there has sprung up on many of the Continental railways, and particularly on some German lines, a strong predilection for 4-wheeled tank and tender locomotives; and so extensively are such engines now being employed for almost all classes of traffic on the railways to which we refer, that it appears to us desirable that we should consider here their advantages and disadvantages. First, then, it is claimed for the 4-wheeled engines, by those who advocate their employment, that they are less costly than the 6-wheeled type; that the whole weight is available for adhesion; that they pass readily round curves; and that there is a less variation of the load on the different wheels when the engines are running than occurs with 6-wheeled locomotives. That the advantages thus claimed are important, it is impossible to deny, and the only question is, therefore, whether they can really be obtained by building locomotives with 4 wheels only. With the exception of the first advantage mentioned, namely, that of less cost, it is, however, we consider, extremely doubtful whether the claims can be substantiated, while even as regards saving of cost, we doubt whether there is really so much in it as the advocates of the 4-wheeled engines appear to imagine. It is undoubtedly true that with a given amount of boiler power, and a given size of cylinder, an engine will cost less if carried on 4 wheels than if mounted on 6; but the difference is, in our opinion, not sufficiently great to counterbalance the extra risk involved in running the 4-wheeled engines. If an engine be mounted on 4 wheels only, the springs must be heavier, the bearings and axle-boxes larger, and the axles stronger than would be required for the coupled wheels of a 6-wheeled locomotive of the same total weight; while the frame, being less efficiently supported, will also require additional strength to give it the same power of resistance which it would possess in a 6-wheeled engine. These various matters combined will go no inconsiderable way towards counterbalancing the cost of a third axle and pair of wheels, and the fittings connected with them.

The claim that in the 4-wheeled engines all the weight is available for adhesion must be allowed; of course; but whether this is in all cases an advantage or not is another matter. The truth is, that the amount of adhesion required to turn to account the whole power which a locomotive is capable of developing varies, inversely, according to the speed at which the engine is run; the higher the speed, the less being the adhesion required. Thus, let us suppose the case of a locomotive having a boiler of such size as to be capable of supplying steam sufficient to develop in the cylinder 10,000,000 foot-pounds of work per minute over and above that required to overcome the frictional or other resistances of the engine itself. If, now, the engine is moving at a speed of but 1,000 ft. per minute, or a little under 12 miles per hour, a pull of 10,000 lbs. will have to be exerted to use up the power developed, and the adhesion weight will have to be such as will enable this pull to be exerted without causing the engine to slip. If, however, the speed of the er gine be increased to 5,000 ft. per minute, then the pull necessary to use up the 10,000,000 foot-pounds of available work developed per minute in the cylinders would be $\frac{10,000,000}{5,000} = 2,000$ lbs. only, and the adhesion weight required would be only $\frac{1}{5}$ of that necessary in the case first supposed. Thus, although in the case of engines travelling at slow speeds it is desirable to have a great proportion of the weight

available for adhesion, yet in the case of fast-running engines this is by no means always necessary, particularly if the trains worked by such engines do not require to be started very quickly. While, therefore, the 4-wheeled arrangement possesses an advantage when adopted for shunting engines or goods engines travelling at low speeds, the fact of it enabling all the weight available for adhesion ceases to be an advantage when the speed becomes higher. Thus, on the Rhenish Railway—where some 4-wheeled tank engines are in use, working the traffic for the steam ferry at Duisburg, and where, also, 4-wheeled goods engines are employed for hauling the coal and mineral trains on the Osterath-Wattenscheid line—it has been found that, although these locomotives are capable of exerting great tractive power when moving slowly, yet that it is impossible to keep up sufficient steam to maintain this tractive effort at a higher speed. For this reason the 4-wheeled engines are not used on the main line of the Rhenish Railway, as, the load on each axle already averaging 15 tons, the boiler power cannot be increased.

As regards the power of traversing curves easily, there is much to be said against as well as in favor of 4-wheeled locomotives. At low speeds such engines do, from their short wheel base, undoubtedly get round curves well, but at anything like a high speed this short wheel base, combined with the overhanging weight, occasions a great wear of the wheel flanges when curves are being traversed In the majority of cases, also, the drawbars are arranged so that the pull exerted on the train acts at a considerable leverage in opposition to the guiding force exerted by the wheel flanges, and thus increases the wear of the latter. To a great extent, however, this wear due to the pull exerted on the train is a preventable evil, and we shall not, therefore, urge it as an inherent objection to the 4-wheeled system. Quite apart from this, however, the shortness of the wheel base of the 4-wheeled engines exaggerates the effect on the permanent way of all lateral oscillations, whether on curves or straight lines, and this increase of effect, of course, shows itself on the wheel flanges. Thus on the Saxon State Railway, where a number of 4-wheeled locomotives are in use, it has been found that in these engines the wear of the leading tyres is greater than in the case of 6-wheeled engines with a 2 ft. longer wheel base. On the Dresden and Chemnitz branch of this railway there are in use some 4-wheeled engines, weighing, in working order, 27½ tons, some of these engines having 4 ft. 6 in., and some 5 ft. wheels, while the wheel base is 8 ft. 6 in. The tyres of the 4 ft. 6 in. wheel engines are found to run on an average 20,350 miles, and those of the 5 ft. wheel engines 14,200 miles before re-turning becomes necessary, while the tyres of some 6-wheeled engines, weighing 37 tons, and having 4 ft. 6 in. wheels, with a wheel base of 10 ft. 4 in., run 19,900 miles without the tyres being turned. It should be mentioned, however, that in these latter engines the trailing and leading wheels were transposed after 14,200 miles had been run. The authorities of the Saxon State Railway, in the report made by them the year before last to the German Association of Railway Engineers, affirmed that the 4-wheeled engines were very unsteady on the curves, and that even on straight and level lines they were not considered fit to run at speeds of over 6 German miles (= 28¼ English miles) per hour. Similar reports were also obtained from some other lines, but it is only fair to state that precisely opposite evidence was afforded by several railways, the authorities of the Wurtemburg State Railway in particular affirming that the 4-wheeled engines employed by them run easily over curves, show no lateral oscillation at high speeds, and are, in fact, equal in this respect to the best 6-wheeled engines.

The assertion that in 4-wheeled engines there is a much less variation of the load on the axles than in the 6-wheeled type, is one for which we believe there is no foundation whatever. In fact, both theoretical considerations and practical experience are directly opposed to it. All who have ridden on the old 4-wheeled locomotives of the Bury type, formerly largely used in this country, will well remember how those engines used to "gallop" at high speeds, while at the present day it is only necessary to ride on the foot-plate of an ordinary contractor's 4-wheeled tank engine and watch the action of thesprings, to be convinced that the latter are in 4-wheeled engines by no means free from

variation of load. Notwithstanding these facts, however, great equality of load on the springs has been extensively claimed as a special attribute of 4-wheeled engines, and even Baron von Weber, whose admirable researches on the stability of permanent way are familiar to our readers, has gone so far as to condemn 6-wheeled engines in favor of 4-wheeled, almost exclusively on account of this supposed good quality. In December, 1870, we published an account of the Baron's ingeniously conducted experiments in 6-wheeled locomotives, and gave a Table containing a summary of the results he obtained. These results showed that in the case of leading wheels carrying a normal load of $5\frac{3}{4}$ tons per wheel this load was sometimes increased when running to over 9 tons, and sometimes diminished to but $1\frac{1}{2}$ tons; while in the case of another engine, of which the wheels had a normal load of 3.65 tons, the load rose in some cases to 7.35 tons, and actually fell in others to as little as 5 cwt. only—an amount less than $\frac{1}{14}$ the normal load. These and other similar results obtained from the 6-wheeled engines on which the experiments were made appear to have led Baron Von Weber to condemn such engines altogether, for he advocates strongly the exclusive use of 4-wheeled engines. Besides, however, the rough-and-ready experience to which we have alluded, exact experiments are available to prove that the asserted maintenance of equal loads on the wheels of 4-weeled engines is a purely imaginary quality. Such experiments were carried out some time ago on the Saxon State Railway, with some 4-wheeled engines, having a normal load of 7 tons per wheel, when it was found that while running, this load fell to as little as 4 tons, and increased to as much as $11\frac{1}{4}$ tons. The engine on which the experiments were made had an independent spring above each axle-box; but there are also on the same line some other 4-wheeled engines in which the weight is carried on 3 points only, the 2 trailing springs being connected by a transverse lever. These engines are said to run steadier than the former, but less freely. The variation of load recorded during the experiments with the 4-wheeled engines on the Saxon State Railway is undoubtedly less than that registered during Baron von Weber's trial of 6-wheeled engines; but it is also undoubtedly in excess of the variation which occurs in 6-wheeled engines properly mounted on their springs, so that the weight is carried on 3 points only.

We do not hesitate to say that an engine with 4 coupled wheels of which the springs are connected on each side by compensating beams, while either the leading or trailing end of the engine is supported centrally on a properly constructed bogie, possesses a degree of freedom from variation of the load on the wheels which cannot be obtained in any ordinary 4-wheeled type of engine.

We have hitherto said nothing respecting the disastrous results attendant upon the fracture of an axle of a 4-wheeled engine, and it is really unnecessary that we should enlarge upon the point. Altogether we consider that the balance of evidence is decidedly opposed to the conclusion that a 4-wheeled type of locomotive can be satisfactorily employed for any but slow traffic, or for shunting purposes. For such uses 4-wheeled engines may undoubtedly be very frequently employed with advantage, and had their use been confined to such services, we should have had little or nothing to say respecting them here. As it is, however, we cannot but regard their increasing employment on the Continent for working fast passenger traffic with a certain amount of apprehension, and we fear that the practice of so employing them may eventuate in a sad lesson, the results of which, although they may be deplored, will be irremediable.

REPORTS OF ENGINEERS' SOCIETIES.

ANNOUNCEMENTS TO MEMBERS AND ASSOCIATES.—I. Is is believed that several names of members and associates elected at the Bethlehem meeting in August, 1871, have been accidentally omitted by reason of a loss of the portion of the records of that meeting. Such persons or their friends are requested to communicate with the secretary.

II. All members and associates who have not paid their dues, are requested to do so at once, by sending in postal orders, or check or money, $10 to the secretary.

All members and associates who pay their dues for each current year, strictly in advance, will have sent to their address regularly and weekly, the "Engineering and Mining Journal," which is the organ of the Institute, and will contain the proceedings and transactions, and all important

papers read before the Institute, and all notices of meetings. Back numbers cannot, as a general rule, be sent.

III. It is expected that the more important papers read before the Institute, and the debates thereon, will be published in annual or semi-annual volumes, to which those members and associates will be entitled who have paid their dues.

IV. Authors of papers are requested to notify the secretary in advance of the meetings, giving the subject and length of their papers. Attention is also called in this connection to rules 12 and 13.

V. The next meeting of the Institute will be held in Philadelphia, beginning on Tuesday, February 20, 1872, at 8 P. M. The Council will meet at 3.30 P. M. of the same day. Messrs. Lesley, Drown, Blandy, Fraser, Gaujot, and Lyman are the local committee of arrangements. The sessions will be held at the University of Pennsylvania, in Ninth street, above Chestnut, and the headquarters of members will be at the Bingham House, corner of Eleventh and Market streets.

Martin Coryell, Secretary, Wilkesbarre, Pa.

THE DERBYSHIRE INSTITUTE OF MINING, CIVIL, AND MECHANICAL ENGINEERS.—The second meeting in connection with the above Institute was held at Chesterfield, under the presidency of Lord Edward Cavendish. It was stated that not fewer than 21 new members had just been admitted. Papers were read by Mr. E. Bromley, "On Hydraulic Engines;" by Mr. R. Howe, "On the Guibal Fan Experiments;" and "On Machinery for Washing and Separating Coal and Mineral Ores," by Mr. Howard. An animated discussion followed the reading of each paper, but as the subjects contained in the two last papers had not been properly ventilated the discussion was adjourned. The desirability of erecting a memorial hall to the late George Stephenson was introduced to the meeting by Mr. C. Binns, of Clay Cross, one of the vice-presidents of the Institute, who showed the great necessity of erecting such a building in a town near to which Stephenson once resided, and in which he was interred. He, however, intimated that, as an effort was being made for obtaining funds to enlarge the accommodation at the hospital, the Council had thought it better to let the matter rest for 12 months, until the hospital scheme was completed.

THE AMERICAN SOCIETY OF CIVIL ENGINEERS.—At the meeting held on the afternoon of January 17th last, Mr. Theodore Allen read a paper describing an apparatus operated with hydraulic power, used along shore, by the New York Department of Docks, to take soundings for permanent foundations, down to solid earth, or bed rock; whereby a pointed hollow steel shaft, connected by a cross-head with two hydraulic cylinders, was forced downward from a floating scow, through mud and soft earth, until a resistance was met superior to the water pressure within the cylinders.

A discussion followed upon the manner of sounding for foundations, and of sinking salt and oil wells.

Mr. Collingwood called attention to the operation of the pneumatic siphons used to remove material from the west caisson, New York bridge; and the difficulty experienced, from the rapid cutting away of the elbows in the pipes by the upward currents of sand.

A large and valuable donation to the library of the Society by Mr. Arthur was announced.

At the meeting held in the evening of February 6th last, Mr. Collingwood presented an investigation of the amount of air required for healthful respiration, within the west caisson of the New York bridge; the number of laborers employed therein, and of gas lights burned, being taken into account.

Mr. Macdonald read a paper upon the "Strains in a triangular roof truss, and the use of counter braces in lattice bridges," showing the errors made by recent writers upon these topics.

Samples of tool steel from the American Chrome Steel Works were exhibited.

IRON AND STEEL NOTES.

DEPHOSPHORIZING IRON ORES.—Metallurgists have for a long time past made great efforts to discover some practical method of dephosphorizing iron ores which would enable them to utilize many varieties of ore which, owing to the presence of phosphorus, yield only an inferior quality of iron. The quantity of ore so contaminated is enormous in many of the more recent geological formations, such as the oolitic, cretaceous, and tertiary formations, where the ore is either found in the shape of a carbonate or a hydrate of iron, always intimately contaminated by phosphate of lime. Of this character are the heavy beds of iron ore in the Middlesbrough district, in Luxembourg, Lothringen, Bavaria, Hanover, Bohemia, and many other localities. It was the phosphorus which forbade the use of a number of these ores for many years, until modern metallurgists had learnt, by using larger furnaces and more limestone, and by adopting a judicious admixture of other ores, to extract a cheap and tolerable iron from them. Nevertheless, it has always been a desideratum to neutralize the injurious influence of the phosphorus in one way or the other. Some engineers have endeavored to extract the phosphorus from the ore, wherein it is contained in the shape of basic phosphate of lime, which is insoluble in water, and the object of all their exertions being to render this compound soluble by converting it into acid phosphate of lime by the action of other mineral acids, which would combine with a part of the lime, and set an equivalent of the phosphoric acid free to combine with the rest of the phosphate of lime, thus forming a super-phosphate. This idea is stated to have been lately successfully carried out by T. Jacobi, of Adalberthutte, at Kladno, near Prague, by exposing the ore to a solution of sulphurous acid in water, or to the simultaneous action of sulphurous vapors and cold water, when this acid forms a soluble compound with the lime, and at the same time converts the rest of the phosphate to the soluble form, so that it can be washed away with cold water. The inventor exhibited his process during the last meeting of the Association of German Engineers and Architects, at Prague, on November 3d, 1871. The samples of fibrous and fine grain bar iron and puddled steel made from such dephosphorized ore, and produced to the Association, were of an excellent character, and

found unanimous approval. The sulphurous gas is either produced by burning sulphur or by the calcination of pyrites or other minerals containing sulphur. The same end has been attained by another engineer, B. Osann, of Potsdam, by employing in a similar way diluted hydrochloric acid, which is obtained very cheaply in quite a novel mode. At the above-mentioned rock salt mines of Stassfurt and Leopoldshall, large masses of chloride of magnesium are obtained, together with the salts of potassium, and are thrown away as valueless. Now, if this chloride of magnesium, which contains always a considerable amount of water, be heated to about 110 deg. Cent., or 230 Fahr., it gives up so much water as to form a trihydrated salt of chloride of magnesium, and if this is rapidly heated to the melting point of lead it is decomposed, giving up vapors of hydrochloric acid, when hydrate of magnesia is left as residue in the retort. The hydrochloric vapor acts exactly as was described of the sulphurous acid. Both of the processes above described are worthy of attention; but the information we have received concerning them is not as yet sufficiently detailed to enable us to form any decided opinion regarding their practical merits. Other metallurgists have sought to get rid of the phosphorus during the puddling of the iron, or even just before, when the pig iron runs from the taphole in the moulds. For removing the phosphorus during the operation of puddling, Director Spamer, at Ilsederhutte, in Hanover, adds to each heat of 500 lbs. of pig iron about 6 lbs. of fluoride of calcium (fluorspar), which readily melts when brought in contact with the iron, so that it can be intimately mixed with it, when the fluorine combines with the silicon of the iron to fluor silicon, and phosphoric acid is absorbed by the lime and carried into the tap cinder; or finely powdered fluorspar is thrown into the iron moulds before they are filled with liquid iron when tapping the blast furnace. In both instances the result obtained is said to be excellent, the cold-shortness of the bar iron having entirely disappeared. This appears to be a modification of the Henderson process, which has lately attracted much attention in this country.—*Iron Age.*

STEELED WHEELS.—This novel title is given to railway wheels made by a process which must rank among the great improvements recently made in the working of metals. We refer to the improvements in car wheels, patented in 1868 by Mr. W. G. Hamilton, engineer, of the Ramapo Wheel and Foundry Co., which, after 4 years of experimental trials, is now brought prominently before the public.

Mr. Hamilton, who is well known to the railway profession, through his "Manual of Useful Information for Railway Men," has worked out the problem of making chilled car-wheels out of non-chilling irons, and at the same time increasing the strength of the mixture above that of the most expensive charcoal irons.

The process consists in part in melting scrap steel, with the ordinary charge of pig metal, in the cupola, by which an increase of strength of from 20 to 50 per cent. is given to the metal.

Messrs. A. Whitney & Sons, the extensive wheel founders of Philadelphia, who have been testing the practical utility and value of the process, have made some 15,000 wheels, during a continuous working during the last 3 months, and report it a most complete success.

That this process will enable them, by adding to their usual chilling charcoal irons a portion of non-chilling soft charcoal irons, or anthracite metal, to produce a car wheel of greater strength, and at a much less cost, than with high-priced chilling charcoal irons alone.

To the railway community the value of this improvement will be understood, when it is known that the supply of charcoal irons is yearly diminishing and the cost increasing, and that the steeled metal gives greater security to their rolling stock. A company has been organized to grant licenses to manufacture, under the name of The Hamilton Steeled Wheel Co. of Philadelphia, of which J. Edgar Thomson, of the Pennsylvania R. R., is the president; Mr. Hamilton vice-president, with a board of direction, amongst whom are—Thos. A. Scott, M. McCullough, Henry L. Pierson, A. J. Cassutt, and other prominent railway men.

RAILWAY NOTES.

THE CANAL CAVOUR.—A Milan paper gives the following as the revenue derived from the Canal Cavour during the last five years:

	Francs.
1866	438,000
1867	494,000
1868	729,500
1869	733,000
1870	885,000

This does not include the revenue derived by the Company from the State canals purchased from the Government. It may safely be anticipated that, after the completion of the important branch canals now in construction, the revenue of the company will increase considerably, and render it a most profitable undertaking.—*Journal of the Society of Arts.*

MACNAIR'S INVERT PERMANENT WAY.—A trial of this way has recently been made upon the North London Railway. It has had a trial of 18 months on the North British Railway, and a sample has been in wear on the North London line for 3 months. The North London line is laid with double-headed steel rails of 80 lbs. weight to the yard, their depth being 5½ in. The locomotives traversing the line weigh 45 tons, with 14 tons weight upon each pair of driving-wheels. A part of Mr. Macnair's invert way carries flat-bottomed steel rails of 70 lbs. to the yard, and 4½ in. deep; these are expected to stand the traffic as long as the Company's heavier ones. Another part consists of iron rails of similar pattern 66 lbs. to the yard and 4½ in. deep. The principle of the "invert" is, as the name indicates, a supporting of the rails upon a series of inverted arches, formed by wrought-iron plates, about 3 ft. long, 12 in. wide, and ⅛ in. thick. These are put in loose, and their extremities abut against small butt plates, riveted to the under side of the rail. The rails forming the roadway are connected together by tie-bars, made of common angle iron, placed at suitable intervals, and fasten-

ed by the same rivets. In this manner a roadway of very uniform elasticity is produced. The peculiar motion of the substructure calls into exercise the transverse strength of the rail itself, which, as borne upon the points of the inverts, acts always like a beam in carrying the load rolling over it, the points of support themselves yielding to the weight as it comes over them, so that even the supporting points take their due places in the common elasticity of the whole. The form of the inverts has suggested to many the idea of springs—a purpose they are in no wise intended or fitted to fulfil; their proper object is correctly expressed in their name, and their action under a train is thus: When the weight comes on the anterior end of the first invert, that end is depressed; the invert then slides slightly forward along the curve of the ballast, on which it rests until the posterior end is elevated in front of the weight, and is thus kept up to its duty of supporting the rail as the load approaches. As the weight travels on, the posterior end of that invert, as well as the anterior end of the next invert, are then depressed, the posterior end of the second invert rising up similarly to the support of the rail in front of the load, and as the posterior end of the first invert descends, its former sliding action is reversed until its anterior end is brought up again under the rail behind the load, so that at this stage the rail which forms the beam is supported between the anterior end of the first invert and the posterior end of the second invert, whilst the load itself is over the intermediate ends of them both. When the load is intermediate between the two ends of an invert, they both contribute to the support of the shorter length of rail which then carries the load; and so on along the whole length of the railway, the points of support for the rails, whilst acting as beams, being alternately the two ends of the same invert on the opposite ends of two contiguous inverts. The general conditions of the system, as shown, appear to indicate that there will be a saving in the cost of maintenance, and more durability of the materials, than in any sleeper roadway. In respect to cost, in a general way, it seems to be proved that the invert road will not cost more than an ordinary sleeper road in this country; but abroad, where the expense of transport becomes an important item, the advantage of the invert over the sleeper will be considerable; the weight of the invert road being 190 tons per mile, as against 230 tons per mile for the sleeper road, both carrying the like weight of rails.—*Journal of the Society of Arts.*

RAILWAYS IN ASIA MINOR.—The Turkish Minister of Public Works publishes the following official note on the subject of this enterprise: "The railway in course of construction between Scutari and Ismidt, is one of the numerous public benefits which do honor to the spirit of initiative of His Imperial Majesty the Sultan. His Majesty, gratified with the progress made with this line, and acting upon the regenerating ideas with which he is ever animated, has further ordered the Minister of Public Works, through the Grand Vizier, to establish a network of railways throughout the whole of Asia Minor, by means of branches, communicating with the Scutari and Ismidt line. In conformity with the Sultan's order, engineers have been sent to Ismidt to examine Mount Seugud, and to make all necessary surveys, with a view to the extension of the line to Eski-Sheir, as a first instalment of His Majesty's splendid scheme. As the works on the Scutari to Ismidt line are comparatively far advanced, considering the time employed upon them, there is reason to believe that this section will be completed by next September, that the extension to Eski-Sheir will be in readiness during the following spring, and that both lines can then be joined. The important subject of the branch line is now under earnest consideration at the Ministry of Public Works.—*Journal of the Society of Arts.*

PHILADELPHIA AND READING RAILROAD.—The production of rails at the Company's rolling-mill during the year amounted to 19,113 tons, at a cost of $64.69 per ton, including in the cost the old rails re-rolled, at an estimated value of $45.03 per ton.

The following table shows the product of the mill for each year since its erection, with the number of tons of each year's production since removed from the track:

YEARS.	1868. Tons.	1869. Tons.	1870. Tons.	1871. Tons.	TOTAL. Tons.
Product	8,971	17,037	17,557	19,113	62,678
Worn out, 1868 ...	5				5
" 1869 ...	175	2½			177½
" 1870 .	904	164½	1½		1,070
" 1871 .	1,418	614	240	3½	2,275½
Total worn out	2 502	780¾	241½	3½	3,527¾
Per cent.....	.279	.046	.014	.00018	.056

From this statement it will be seen that of the 62,678 tons of rails rolled by the Company and laid in the track during the last 4 years, but 5/6 per cent. have yet been worn out. Of the production of 1868, 27 8/10 per cent. have been removed up to this time, showing that 72 2/10 per cent. of the first year's manufacture are still in use, although a tonnage of over 20,000,000 has been moved over them at speeds varying from 10 to 40 miles an hour.

KANSAS and her railways have received the personal attention of Mr. Samuel Bowles recently. He says, in the "Springfield Republican":

"Kansas is sure of a large population and great wealth. Railroads are rapidly opening up all her rich fields to population and improvement. No State of all the new West can hope to surpass her in the power of her materialism, and no State among them all is so pledged as she by the prayers and patriotism that labored over her birth, to direct and govern this power with a high moral sense, and inspire her wealth with spirituality. If she fails to prove something like the Massachusetts of the West she will certainly be false to her birthright and stand as a discouragement to holy effort.

ENGINEERING STRUCTURES.

THE SUPERSTRUCTURE OF THE ST. LOUIS BRIDGE.—A full sketch of the novel and extraordinary difficulties encountered in manufacturing and testing the materials for the superstructure, and of the original, ingenious, and very costly means by which they are now at length completely overcome, would form one of the most instructive and fascinating chapters in the history of practical engineering. They relate, mainly, to the preparation of the steel work, of which the quantity and proportions of its parts are not more unprecedented than was the securing of a quality capable of bearing the very exacting tests. The Keystone Bridge Co., of Pittsburgh, contractors for the entire superstructure, sub-let the contract for the steel to the Wm. Butcher Steel Works, of Philadelphia, who, at the outset, made additions to their buildings, furnaces, rolling mills, straightening machines, etc., which seemed to give assurance of success and dispatch. The first large forgings required were the steel anchor bolts, from 22 to 36 ft. long, and 5¾ in. diameter. Each bolt is required to sustain, tested at the shop, a tensile strain of 519 tons without permanent elongation – being twice the maximum strain to which it can be subjected in the bridge. The first testing machines made were themselves broken before the first bolts were proved to be defective. Among many curious accidents that occurred, was the breaking off of a piece of bolt 20 ft. long, and weighing more than half a ton, and shooting it "like an arrow" 60 ft. away; at the same time the recoil of the portion of the bolt still in the machine broke the piston rod from its fastenings, by reversal of the tension strain, and drove it clean out of the ram at the other end of the hydrostatic cylinder. Months were lost, and tens of thousands of dollars expended by the sub-contractors before the first bolt was made capable of sustaining a strain which it was next to impossible for machinery to impose. Up to the present time, 24 of the entire 50 required have been tested and accepted, of which 18 have gone to the Keystone Works to have the screws cut upon them. This result has been attained, after long delay, by trying new mixtures of steel, and exercising greater care in its manipulation.

Equally difficult, though in a different way, proved the manufacture of the steel tubes forming the arches of the spans, amounting to about 4-5ths of the entire steel required in the bridge. These tubes are to be 13 ft. long and 18 in. diameter, and they are each composed of 6 staves of the length of the tube, each 9½ in. wide, and from 1¼ to 2¼ in. thick. The first rolls (made, of course, especially for this) proved defective, and weighing several tons, had to be removed to the shop, several miles distant. It was first attempted to roll them with the rib on each side, the staves projecting into the tube; but this was abandoned, necessitating the working of a new set of rolls, 12 in number, which went back to the shop two or three times before they turned out perfect staves. From these causes 6 months elapsed before the first stave was brought to the testing machine; and this done, the steel proved inferior. New mixtures of steel at length resulted in a perfect stave, and then the new difficulty was met, that staves made from the same formula had different degrees of strength, due, probably, to varying degrees of heat altering the proportions of carbon and iron. [The same had been true of the anchor-bolts.] This unfortunate result —experienced by a great loss of time and money to both the Keystone Company and the Butcher Works – led to investigation after some method, if possible, which would give an assured result with less skill and caution. Fortunately—providentially, one should perhaps say—Mr. Eads, before the contract with the Keystone Company was made, had his attention turned to the process of the manufacture of chrome steel, and to a thorough test of its capabilities, which had satisfied him of qualities eminently adapting it to bridge superstructure. Chromium, unlike carbon, is a metal; it has slight affinity, if any, for oxygen, and is not affected by heating. It forms an alloy with iron, from which heat does not expel it as it does carbon in "burnt steel." Chrome steel, according to the description, is more like steel than carbon itself. Beneath the rolls it works more smoothly, adapting itself perfectly to the form of the roll; and its products are very uniform in quality, being unaffected by variations in intensity of the heat. In 1869 Mr. Eads passed two entire days in a confidential inspection of the process of its manufacture, under the personal supervision of Mr. C. P. Haughian, Superintendent of the Chrome Steel Co., sole manufacturer under the patents of Mr. Bauer—assisted by Commodore J. W. King, Chief of the U. S. Bureau of Steam Engineering, and his own Chief Assistant, Col. Flad. Though thoroughly convinced of its superiority, indeed, of its adaptation alone among known varieties of steel to the demands of this structure, he could not under the contract stipulate for its use by the Keystone Co., whose privilege it was to open the sub-contract to competition among steel makers, several of whom declared their ability to furnish the required product. He was the more ready to do this, inasmuch as he had also, while in Europe, in the course of a personal examination of the establishments of Krupp and Peten Godet, received assurances that the requirements of this bridge could be met with carbon steel. The result of all is, that the Wm. Butcher Co. have now secured the right to use the chrome steel for the bridge; and during September 100 trial staves were made from Mr. Haughian's formula and under his direction—all beautifully and perfectly rolled, and all bearing the requisite test. With the decision to use this product exclusively hereafter, Mr. Eads considers the chief difficulty in the way of the reasonably early completion of the bridge surmounted. The bars produced have a tensile strength in excess of the specifications; while under compression the resisting power of the chrome steel may be indefinitely increased (in

hardness even beyond cutting power of any lathe) by the addition of chromium.

IRON WORK.—Of scarcely less interest are the skewback plates, sunk in the face of the abutments, against which the ends of the steel arches are placed, and which sustain their entire thrust. These plates, 48 in number, are 7 ft. long, 3 ft. wide, and 6 in. thick, and are made of wrought iron. They are secured to the masonry by the anchor-bolts referred to above, 5¾ in. diameter. These bolts, 4 in the lower and 3 in the upper skewbacks, sustain no portion of the weight of the arches; their province is simply to prevent any displacement of the ends of the arches which might otherwise occur from wide variations of temperature, unequally distributing the weight imposed on the arches. Finally, difficulty has been experienced by the sub-contractors (under the Keystone Co.) in making the main braces connecting the upper and lower members of the arches, and second in importance only to the steel tubes of the arches themselves. Under the specifications, these braces (of iron) were to be tested to a tensile strain of 60,000 lbs. per sq. in. The iron thus far furnished under the sub-contracts has failed at from 48,000 to 54,000 lbs. Assurances (based on tests) are now given, however, that iron of the requisite quality will speedily be furnished.

COST OF THE WORK.—The original estimate, including land damages, was $4,686,475.44; the total expenditures to Sept. 1, 1871, amounted to $3,616,560.99; the additional amount required to complete the bridge is $1,949,497.17; making the entire cost of bridge and approaches $5,566,058.16—an excess of $1,479,582.72. It has since been found, however, these estimates are about $1,179,000 too low; the excess of the actual cost of the work over the estimates being satisfactorily accounted for by Mr. Eads.—*Iron Age.*

BORING of mining shafts is an ordinary operation in Germany and France, when the want of cohesion or the abundance of water in the ground prevented the adoption of the ordinary method of sinking and securing the shaft by either timbering, masonry, or iron tubtings. In Westphalia, the coal measures are, as a rule, covered to a certain depth, which increases toward the northward, by thick beds of marl belonging to the chalk formation. Though these beds often contain very much water, they are generally sufficiently coherent to confine the water between certain strata, and to allow the gradual sinking and excluding of water by water-tight tubtings or other means, until the coal measures are reached, which are generally pretty free from water. At the Dahlbusch mine, however, the marl was so much intersected by vertical fissures, that there was no hope for isolating the water of the various strata which had to be passed through, and it was resolved to bore, by means of steam engines, two shafts, the first of 2 metres, the second of 4.39 metres diameter, and both of 50 fathoms depth. When both shafts had reached a stratum of marl, considered to be sufficiently compact and water-tight, a column of cast-iron tubtings, weighing in the second instance not less than 420 tons, was gradually sunk down upon the bottom, so that between the tubting and the wall of the shaft an annular space was left, which was filled up with concrete, and so effectually excluded the water, that the bottom appeared dry after the water had once been emptied out, while during the boring operations 12 cubic ft. of water per min. rose from the shaft's opening. The total cost per 1 fathom depth was £135 for the narrow air-shaft, and £292 for the principal shaft. It is, however, very probable that the cost and time would have been very much less, if, instead of boring the shafts, compressed air, in combination with cast-iron tubtings, had been employed from the very beginning in sinking them after the usual method.

THE SUTRO TUNNEL REPORT.—The report of the Commissioners sent by the Government to investigate, and report upon the feasibility and true merits of the Sutro tunnel, and upon the expediency of extending Government aid to the enterprise, has been submitted to the Senate. The following vague abstract from it was transmitted some time ago by the telegraph:

"The Commissioners report that the tunnel is entirely feasible, and may be constructed in less than 2½ years, at a cost of about 4½ millions. They believe that the Comstock lode is a true fissure vein, continuing down indefinitely, and express the opinion that while the tunnel is not a necessity for ventilation or draining, yet any scheme which promises increased economy in the working of the mines and rendering valuable a vast amount of now worthless low-grade ores in the Comstock lode, becomes of national importance. Whether the Sutro tunnel project fulfils this condition of economy depends on the efficacy of the methods now employed in Germany and other countries of Europe for the concentration and profitable working of low-grade ores. On this point the Commission has not, in this country, by personal investigation, been able to obtain the desired information. In conclusion, the report commends the Sutro tunnel to favorable consideration, as an exploring work for deep mining.

BOOK NOTICES.

PRACTICAL GEOMETRY. By E. WYNDHAM TARN, M. A. London: Lockwood & Co.

This is a manual for the practical man, whether architect, engineer, or mechanic, and contains simple rules for the delineation of various geometrical figures employed for useful and ornamental purposes. No demonstrations of the rules laid down are given, the object of the author being to avoid all abstruse formulæ or complicated methods, and to enable persons with but a moderate knowledge of geometry to work out the problems required. Besides the ordinary figures described with straight lines, angles, and circles, there is abundant information on the ellipse, hyperbola, parabola, the catenary, the harmonic curve, the lemniscate, spirals, the involute of the circle, the lituus, and cycloids, the various rules being illustrated by beautifully worked wood-blocks, 164 altogether.

NOTES ON THE THEORY OF THE STEAM-ENGINE. By J. H. COTTERILL, M. A. London: E. & F. N. Spon.

The author of this little pamphlet says that the only English work on the steam-engine based on the true theory of heat is Rankine's "Steam-En-

gine and Other Prime Movers;" but on account of the very difficult form in which many parts of the subject are presented in the work in question, the "Notes" which form the subject-matter of this pamphlet were drawn up to assist the students of the Royal School of Naval Architecture and Marine Engineering, and they are now published in the hope of assisting those who are puzzled by the abstruse manner in which the theory of heat has hitherto been treated. Students of the subject will obtain useful hints from a careful perusal of these "Notes," and a clearer understanding of a theory not by any means remarkable for the perspicuity of its treatment in standard treatises.

LESSONS IN ELEMENTARY ASTRONOMY. By R. A. PROCTOR, B. A. London: Cassells.

Our readers are so well acquainted with the products of Mr. Proctor's pen, and his facile method of teaching scientific truths, that we need not occupy our space with any lengthy remarks on the little book before us. Suffice it, then, to say that these lessons are written in his usual concise style, and form an excellent stepping-stone to a knowledge of the "grand science." The work is abundantly illustrated, the drawings being to scale where possible; and the chapter on the fixed stars will enable any one to find the objects described.

A PACKET OF ASTRONOMICAL PLATES. Bickley, Kent: G. F. Chambers.

We have received from Mr. G. F. Chambers a bundle of astronomical plates, 50 in number, but containing altogether 108 engravings. These comprise representations of sun-spots, the various planets, eclipse phenomena, comets, double stars, star clusters, and nebulæ, the two latter being printed in blue ink, and all beautifully engraved and worked. Those who appreciate the assistance that young astronomers derive from well-executed drawing of telescopic objects will agree with us that this "packet" is worth the money for which it is offered.

SCALES FOR THE READY COMPARISON OF BRITISH METRIC WEIGHTS AND MEASURES. Arranged by A. L. NEWDEGATE, M.A. London: E. and F. N. Spon, 48 Charing Cross.

In the dozen scales which Mr. Newdegate has arranged may be readily found, by any one who has had a little practice with them, the value of any weights or measures of the metric system corresponding to those of our own. The scales possess all the advantages of the most elaborate tables, with the additional one that the proportion between the relative quantities is perceived at a glance. They comprise measures of length, area, solidity, and capacity, together with the reduction of fractional parts of different measures to their corresponding decimal value. Similarly to all methods of performing arithmetical problems without actual calculation, the degree of accuracy which can be obtained depends upon the more or less minute attention bestowed upon the scale. For approximate results, sufficiently accurate in many instances, one operation suffices to give the answer required. When greater precision is desirable, a second or supplementary operation is needed; but in any case the great labor that would be involved by a numerical calculation is entirely obviated. The engineer and architect, especially those who are engaged in designing works where metrical dimensions are used, will find these scales exceedingly valuable in the office. The use of them can be at once understood from the simple directions attached to them, and they, moreover, are presented in a form with which all professional men are well acquainted. The figuring and lettering are both clearly done, and the material is a good stiff card-board, which will stand the wear and tear of an office, which is sometimes no trifle.—*Engineer.*

COLLEGIATE ATLAS. London, Glasgow, and Edinburgh: William Collins, Sons & Co. For sale by Van Nostrand.

Contains thirty-two maps of modern geography, and eighteen maps of historical geography.

The maps are finely colored, and the volume is of suitable size for library shelves.

WHAT ARE THE STARS? By M. E. S. LYLE. London: G. T. Goodwin. For sale by Van Nostrand.

This is a collection of pictures, one hundred in all, of the constellations, beautifully printed, with white stars on black ground. The explanatory text gives full directions to the student for finding the stars of first and second magnitudes.

THE ROYAL INSTITUTION: ITS FOUNDER AND ITS PROFESSORS. By Dr. BENCE JONES. London: Longmans, Green & Co. For sale by Van Nostrand.

Contents: The Life of Count Rumford before the foundation of the Institution. II.—His life after the foundation of the Institution. III.—The early history of the Institution, and the life of Professor Garnett. IV.—The progress of the Institution to the resignation of Prof. Young, with the life of Dr. Thomas Young. V.—Progress of the Institution to the time of Faraday. VI.—Original papers relating to the American war. VII.—Original letters from Dr. Young. Income and expenditure of the Royal Institution to 1814.

THEORY OF HEAT. By J. CLERK MAXWELL. London: Longmans, Green & Co. For sale by Van Nostrand.

This is the seventh of the series of "Text-Books of Science." It presents a thoroughly scientific exposition of the laws governing all the phenomena of heat, so far as at present known.

The ordinary illustrations have been omitted, in order that the definitions and principles might be stated in the fullest manner.

Entirely unlike either Stewart's or Tyndall's works in the same department of physics, it is as valuable in its way as either. Indeed, it forms a good supplement to Tyndall's "Heat as a Mode of Motion," inasmuch as, comprehending all the phenomena so delightfully illustrated there, Prof. Maxwell has summed up in the most concise manner our present science of heat.

RESEARCHES IN THE CALCULUS OF VARIATIONS. By J. TODHUNTER, M.A., F.R.S. London and Cambridge: McMillan & Co. For sale by Van Nostrand.

Students who delight to labor in the higher fields of mathematical research, will gladly receive this essay from the hands of so accomplished an author.

The previous contributions of Mr. Todhunter to

theoretical as well as applied science have been of the most valuable kind, and probably many students who have become familiar with these earlier works will be tempted to venture upon a new field, when thus offered the guidance of so well-known a master, and thus conquer a difficulty which, if presented by other hands, they would have shunned.

EDUCATION AND STATUS OF CIVIL ENGINEERS IN THE UNITED KINGDOM AND FOREIGN COUNTRIES. London. For sale by Van Nostrand.

This sets forth the conventional requirements for the profession of engineering in European countries. The regulations of the technical schools, their courses of study, and the conditions of graduation, are fully set forth. The work is of special value to instructors in scientific schools everywhere.

THE JOURNAL OF THE IRON AND STEEL INSTITUTE. London: E. and F. N. Spon. For sale by Van Nostrand.

This excellent journal appears as full of valuable information as ever. The Donk's Rotary Puddler receives a fair share of attention, both in the text and plates.

MISCELLANEOUS.

A CEMENT to resist sulphuric acid, it is reported, may be made by melting caoutchouc by a gentle heat, and adding from 6 to 8 per cent. of the weight of tallow, keeping the whole well stirred. Then mix in enough dry slaked lime to make the whole of the consistency of soft paste, and finally add 20 per cent. of red lead, whereby the mass, which would otherwise remain soft, becomes hard and dry. This cement, it is asserted, resists boiling sulphuric acid. A solution of caoutchouc in twice its weight of raw linseed oil, aided by heating and the addition of an equal weight of pipe clay, yields a plastic mass, which also resists most acids.

IN France, where the process of electroplating is regulated by law, every manufacturer is required to weigh each article when ready for plating, in presence of a comptroller appointed by the Government, and to report the same article for weighing again when the plating has been done. In this way the officer shows to the fraction of a grain the amount of the precious metal that has been added, and puts his mark upon the wares accordingly, so that every purchaser may know at a glance just what he is buying. In ordinary plating $1\frac{1}{2}$ oz. of silver will give to a surface a foot square a coating as thick as common writing paper; consequently, when silver is worth $1.25 per oz., the value of the silver covering a foot square would be about $1.87. At this rate, a well plated tea or coffee pot is plated at a cost in silver of not more than $1.50 to $2; and the other expenses, including labor, would hardly reach more than half that amount. Electro-gilding is done in like manner. The gold is dissolved in nitro-hydrochloric acid, washed with boiling nitric acid, and then digested with calcined magnesia. The gold is deposited in the form of an oxide, which, after being washed in boiling nitric acid, is dissolved in cyanide of potassium, in which solution the articles to be plated with gold, after due preparation, are placed. Iron, steel, lead, and some other metals that do not readily receive the gold deposit, require to be first lightly plated with copper. The positive plate of the battery must be of gold—the other plate of iron or copper. The process is the same as that above described. The very best electro-gilding does not necessarily add a great deal to the cost of the article plated. A silver thimble may be handsomely plated so as to have the appearance of being all gold for 5 cents, a pencil-case for 20 cents, and a watch case for $1.—*Iron Age.*

SIR H. DAVY has observed that, "in general, the quantity of charcoal afforded by woods offers a tolerably accurate indication of their durability; those most abundant in charcoal and earthy matter are most permanent; and those that contain the largest proportion of gaseous elements are the most destructible. Amongst our own trees," he adds, "the chestnut and the oak are pre-eminent as to durability, and the chestnut affords rather more carbonaceous matter than the oak." But we know from experience, that red or yellow fir is as durable as oak in most situations, though it produces less charcoal by the ordinary process. The following table of the quantity of charcoal afforded by 100 parts of different woods is added, for the information of the reader:—

Kind of Wood.	Watson.	Mushet.	Proust.	Rumford
Oak, dry	22.92	22.6	19	43
Chestnut	....	23 2	....	....
Mahogany	20.82	25.4	....	....
Walnut	26.04	20.6	....	....
Elm	....	19.5	....	43 27
Beech	....	19 9	....	....
Fir	15.62	....	....	44.18
Norway Pine	....	19.2	....	....
Pine	....	....	20	....
Scotch Pine	....	16.4	....	....
Ash	17.71	17.9	17	....
Poplar	....	....	....	43.57
Lime	....	....	....	43.59
Birch	....	17.4	....	....
Sycamore	...	19 7	....	....
Sallow	....	18.4	...	....

In Count Rumford's experiments a longer period was allowed for the process; and, in consequence, his results represent more nearly the real quantities of carbon in each wood than the others. But even according to the common process, it does not appear that the proportion of charcoal is a satisfactory criterion of the durability.

THE article entitled "Graphical Estimates for Earthwork," in our January number, page 84, was written for the magazine by Arthur M. Wellington, C. E., Division Engineer of Michigan Midland Railroad.

AN experiment to determine the comparative durability of different woods is related in Young's "Annals of Agriculture." Inch and a half planks of trees from 30 to 45 years' growth, after 10 years standing in the weather, were examined and found to be in the following state and condi-

tion:—Cedar, perfectly sound; larch, the heart sound, but sap quite decayed; spruce fir, sound; silver fir, in decay; Scotch fir, much decayed; pinaster, quite rotten; chestnut, perfectly sound; abele, sound; beech, sound; walnut, in decay; sycamore, much decayed; birch, quite rotten. This shows at once the kind that are best adapted to resist the weather; but even in the same kind of wood there is much difference in the durability, and the observation is as old as Pliny, that "the timber of those trees which grow in moist and shady places is not so good as that which comes from a more exposed situation, nor is it so close, substantial, and durable;" and Vitruvius has made similar observations. Also split timber is more durable than sawed timber, for the fissure in splitting follows the grain, and leaves it whole, whereas the saw divides the fibres, and moisture finds more ready access to the internal parts of the wood. Split timber is also stronger than sawed timber, because the fibres, being continuous, resist by means of their longitudinal strength; but when divided by the saw, the resistance often depends upon the lateral cohesion of the fibres, which is in some woods only $\frac{1}{20}$th of the direct cohesion of the same fibres. For the same reason whole trees are stronger than specimens, unless the specimens be selected of a straight grain, but the difference in large scantlings is so small as not to be deserving of notice in practice.

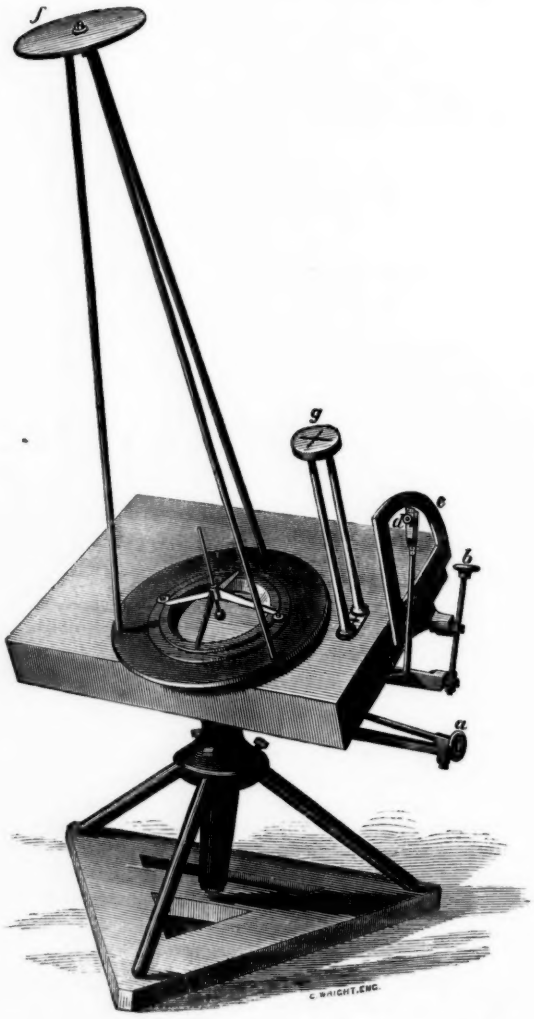
ADULTERATED CEMENT.—At a meeting of the Chemical Society of Newcastle, not very long ago, the President of the Society (Mr. John Glover) read the following statement, which calls for further publicity:—

"During the last few days I have learned that large quantities of blast furnace slag is being ground with Portland cement in this district, and as in the analysis of such cement great stress is very properly laid on its percentage of hydrated silicic acid, I have thought it well to draw your attention to the fact, as blast furnace slag, on being treated with hydrochloric acid, yields a large percentage of hydrated or gelatinous silica, although it has not the slightest value as a cement. You will see from what I have said that a chemist, proceeding to the analysis of a cement so adulterated, might be misled if he were not aware of such adulteration. As a proof that such adulteration is a fraud on the purchaser, I have caused the following experiments on the cohesive power of a pure cement, and of the same cement mixed with slag, to be tried:—The average of a number of bricks of pure cement carried a weight of 485 lbs., and broke with a weight of 492 lbs.; while the same cement, mixed in the proportion of equal parts of cement and slag, bore a weight of only 301 lbs. and broke with 308 lbs. A mixture of the same cement, in the proportion of three of cement to one of slag, bore 375 lbs., and broke with 382 lbs., and each brick was made in the same mould, and was allowed 7 days to harden. You will see from these tests that a purchaser of such cement will not be able to mix with it the same amount of sand as when he buys the pure article, as the slag already mixed with it has taken the place of so much sand, and is really of no greater value than sand, as bricks mixed with sand in the same proportions as when slag was used, gave nearly the same results. If slag gives a better appearance or color to Portland cement, a fair trader should state the fact of its presence, so that his customer might know the price he is paying for such qualities. If our analytical chemists would undertake to test the physical properties of cement, such as cohesion, hardness, etc., as well as its chemical composition, they would supply a want, as there is no such public tester, at least in this neighborhood."

THE Taranaki iron-sand, one of the valuable mineral products of New Zealand, is again attracting considerable attention. A series of experiments undertaken under the direction of the Government apparently proves that steel of the highest quality can be produced at a *minimum* cost and by the most simple process. The iron-sand as taken from the beach is mixed with an equal quantity of clay and of the ordinary sea-sand, which contains a very large admixture of shell. These materials are worked up into bricks, which are hardened in a kiln, then broken up into irregular pieces, which are smelted in an ordinary cupola furnace. The product of this simple process is cast steel of the finest possible texture, from which some beautiful specimens of the finest cutlery have been manufactured. The experiments were conducted by a mechanic in the Government employ, who was restricted to an expenditure of £100, and was therefore only able to erect a furnace of the most temporary description. He, however, succeeded in producing at the first and only trial 5 cwt. of pure steel in the manner I have endeavored to describe, and his success seems likely to lead to further and more extensive efforts to utilize the almost inexhaustible deposits of this ore which exist at Taranaki and elsewhere.—*Times Correspondent.*

A PROCESS devised by Mr. Nagel, of Hamburg, for coating iron, steel, and other oxidizable metals with an electro deposit of nickel or cobalt, consists in taking 400 parts, by weight, of pure sulphate of the protoxide of nickel by crystallization, and 200 parts, by weight, of pure ammonia, so as to form a double salt, which is then dissolved in 6,000 parts of distilled water, and 1,200 parts of ammoniacal solution, of the specific gravity of 0.909, added. The electro deposit is effected by an ordinary galvanic current, using a platinum positive pole, the solution being heated to about 100 deg. Fahr. The strength of the galvanic current is regulated according to the number of objects to be coated. For coating with cobalt, 138 parts, by weight, of pure sulphate of cobalt are combined with 69 parts of pure ammonia, to form a double salt, which is then dissolved in 1,000 parts of distilled water, and 120 parts of ammoniacal solution, of the same specific gravity as before, are added. The process of deposition with cobalt is the same as with nickel.—*Iron Age.*

SOME careful soundings of the Baltic have been made by the steamship Pomerania. The greatest depth of the Baltic Sea between Gothland and Windau was found to be 720 ft. At the depth of from 600 ft. to 720 ft. the water was, at the end of July, very cold, the thermometer giving from ½ to 2 deg. Reamur (near the freezing point of Fahr). No plants were found at this depth, and only a few specimens of one or two species of worms were brought up with the clay and mud.

Apparatus for Measuring the Radiant Heat Transmitted by the Sun's Chromosphere.

Constructed by CAPTAIN JOHN ERICSSON.